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THE

MICROSCOPIC ANATOMY

OF

THE HUMAN BODY,

IN

HEALTH AND DISEASE.

ILLUSTRATED WITH UPWARDS OF 400 DRAWINGS IN COLOUR.

BY

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THE
MICROSCOPIC ANATOMY
OF
THE HUMAN BODY.

PART I. THE FLUIDS.

THE constituents which enter into the formation of the body, and by the combination of which the human frame is built up, naturally resolve themselves into two orders, FLUIDS and SOLIDS, the latter proceeding from the former.

In accordance with this natural division of the elements which enter into the composition of the body, it is intended to divide this work into two parts, the first of which will treat of those components of our framework which are first formed—the FLUIDS; and the second will be devoted to the consideration of those constituents which proceed from the fluid elements, viz. the SOLIDS.

Of the fluids themselves, it is difficult to determine upon any subdivision which shall be altogether without objection, perhaps the most practicable and useful division of them which can be made is, into ORGANISED and UNORGANISED.

To the above arrangement of the fluids the following exception might be taken: all the fluids in the animal economy, it may be said, are to be considered as organised, inasmuch as their elaboration is invariably the result of organisation. But it is intended that the words organised and unorganised, when applied to the fluids in this work, should have a very different, as well as a more precise signification, and that those fluids only should be called organised which contain in them, as essential, or at all events as constant constituents, certain solid and organised particles, while those liquids which are compounded of no such solid matters, as essential portions of them, should be termed unorganised.

In the first category, the *lymph, chyle, blood, mucus,* as normal, and *pus,* as an abnormal fluid, would find their places together with the *milk* and *semen.* The fluids of this class, it will be seen, belong especially to nutrition and reproduction, and admit also, naturally, of arrangement into two series; in the first, those fluids which are concerned in the nutrition and growth of the species itself would be comprised, as lymph, chyle, and blood; and in the second, those liquids which appertain to the reproduction, nutrition, and growth of the new species, as the milk and semen, would be admitted.

In the second category, viz. that of unorganised fluids, the *perspirable fluid,* the *saliva,* the *bile,* and the *urine,* as well as probably the fluid of the *pancreas,* and of certain other glandular organs would be found.

This arrangement of the fluids of the human body might be represented tabularly, thus—

FLUIDS.

Organised.

- 1st series.
  - Normal:
    - Lymph.
    - Chyle.
    - Blood.
    - Mucus.
  - Abnormal:
    - Pus.
- 2d series.
  - Milk.
  - Semen.

Unorganised.

- Perspirable fluid.
- Saliva.
- Bile.
- Urine.
- Pancreatic fluid (?)
  - &c. &c. &c.

If the terms ORGANISED and UNORGANISED be objected to, the words COMPOUND and SIMPLE might take their places, and would well express the distinction which characterises the two series of fluids, the former appellation being applied to those fluids which are compounded of both a solid and a fluid element, and the latter to those which do not possess this double constitution.

ORGANISED FLUIDS.

Art. I. THE LYMPH AND THE CHYLE.

It will perhaps render the description of the lymph and the chyle more intelligible, if the observations which we shall have to make on these fluids are preceded by a short sketch of the lymphatic system itself. This system consists of vessels and of glands, which are of the kind which has been denominated conglobate. The vessels have many of the characters of veins, commencing as mere radicles, which unite with each other to form larger trunks, and their interior surface is provided with valves: they arise from all parts of the system, even the most remote; those of the lower extremities and abdominal viscera form by their union the thoracic duct, which, running along the left side of the spinal column, unites with the left subclavian vein, near its junction with the internal carotid, its contents becoming mingled with the torrent of blood in that vein. The lymphatics of the left side of the head and neck, as well as those of the arm of the corresponding side, unite with the same thoracic duct in the superior part of its course. On the right side, however, a smaller separate duct formed by the union of the lymphatics of the upper part of that side of the body, is frequently met with, and this empties itself into the right subclavian vein. All these lymphatic vessels, in their course, pass through the glands above referred to, and in which the fluid or lymph contained by them doubtless undergoes further elaboration. The lymphatics are remarkable for their equal and small diameter, which allows of the passage of the lymph through them by mere capillary attraction; they are also to be regarded as the chief, though not the exclusive, agents of absorption in the system, the veins likewise taking part in this process.

The lymphatics of the upper and lower portions of the body imbibe and carry along with them the various effete matters and particles which are continually being given off by the older solid constituents of our frame, and which are as constantly undergoing a process of regeneration; these they redigest and reassimilate, into a fluid endowed with nutritive properties, denominated *lymph,* and which is poured into the thoracic duct.

Those lymphatics, however, which arise on the surface of the small intestines, and which, passing through the mesentery, join the thoracic duct, have received a special appellation, being called *lacteals:* this name has been bestowed upon them on account of the milk-like appearance of the fluid which they contain, viz. the *chyle,* a fluid derived from the digestion of the various articles of food introduced into the stomach, and which also is emptied into the thoracic duct.

But the *lacteals* are not always filled with chyle; they are only to be found so when digestion has been fully accomplished; when an animal is fasting, they, like other lymphatics, contain merely lymph.

The contents of the thoracic duct likewise vary: it never contains pure chyle, but during digestion a fluid composed of both chyle and lymph, the former predominating, and digestion being completed, it is filled with lymph only.

It follows therefore, that if we are desirous of ascertaining the proper characters of chyle, our observations should not be conducted on the fluid of the thoracic duct, but on that of the lacteals themselves. It is a common error to regard and to describe the contents of that duct, at all times, and under all circumstances, as chyle, and it is one which has led to the formation of some false conclusions.

We will describe first the lymph, next the chyle, and lastly the mingled fluid presented to us in the thoracic duct.

The *lymph* is a transparent colourless liquid, exhibiting a slightly alkaline reaction, and containing, according to the analysis of Dr. G. O. Rees, 0·120 of fibrin, with merely a trace of fatty matter.

When collected in any quantity, and left to itself, the lymph, like the chyle, separates into a solid and a fluid portion: the solid matter consists of fibrin, and contains mixed up with its substance numerous granular and spherical corpuscles, identical with the white globules of the blood; the serum is transparent, and contains but few of the corpuscles referred to.

The *chyle* is a whitish, opaque, oleaginous, and thick fluid, also manifesting an alkaline reaction, and containing, according to the analysis of the gentleman above mentioned, 0·370 of fibrin, and 3·601 of fatty matter.*

There are present in it solid matters of several kinds.

1st, *Minute particles,* described by Mr. Gulliver†, and which constitute the "*molecular base*" of the chyle, imparting to it colour and opacity: their size is estimated from the $\frac{1}{36000}$ to the $\frac{1}{24000}$ of an inch in diameter; they are "remarkable" not only for their minuteness, but also for "their equal size, their ready solubility in æther, and their unchangeableness when subjected to the action of numerous other re-agents which quickly affect the chyle globules."

Mr. Gulliver has ascertained the interesting fact, that the milky appearance occasionally presented by the blood is due to the presence of the molecules of the chyle. This peculiar appearance of the blood, which so many observers have observed and commented upon, but of which none save Mr. Gulliver have offered any satisfactory explanation, is noticed to occur especially in young and well-fed animals during digestion; as also in the human subject, in certain pathological conditions, and sometimes in connexion with a gouty diathesis.

2nd, *Granular Corpuscles,* similar to those contained in the lymph, and identical with the white globules of the blood, but rather smaller than those, and which will be fully and minutely described in the chapter on the Blood. Mr. Gulliver, in his excellent article on the chyle, makes the remark that the magnitude of the globules hardly differs, from whatever part of the lacteal system they may have been obtained.

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* See article "Lymphatic System" by Mr. Lane, in Cyclopædia of Anatomy and Physiology, April, 1841.

† See Appendix to the translation of Gerber's General Anatomy, p. 89.

The granular corpuscles are found but sparingly in the chyle of the inferent lacteals, abundantly in that of the mesenteric glands themselves, and in medium quantity in the efferent lacteals, and in the fluid of the thoracic duct.

3rd, *Oil Globules,* which vary exceedingly in dimensions.

4th, *Minute Spherules,* probably albuminous, the exact size or form of which it is difficult to estimate, and which are not soluble in æther, as are those which constitute the molecular base.

Chyle, when left to itself, like the lymph, separates into a solid and fluid portion: the coagulum, however, is larger and firmer than that of lymph, in consequence of the greater quantity of fibrin which it contains; it is also more opaque from the presence, not merely of the white granular corpuscles, but principally of the molecules of the chyle; the serum is likewise opaque, the opacity arising from the same cause, the peculiar characteristic molecules of the chyle.

The lymph and the chyle may now be contrasted together. Both are nutritive fluids, the nutritious ingredients contained in the one being derived from the re-digestion of the various matters which are constantly thrown off from the older solids, those of the other being acquired from the food digested in the stomach: the one is a transparent fluid, containing but little fibrin, a trace only of oil, and but few white corpuscles; the other is an opaque, white, thick, and oily fluid, more rich in fibrin, and laden with molecules, white corpuscles, oil globules, and minute spherules; the one, therefore, is less nutritive than the other.

It has been asserted that chyle until after its passage through the mesenteric glands would not coagulate; the fallacy of this assertion has been demonstrated by Mr. Lane*, who collected the chyle previous to its entrance into those glands, and found that it did coagulate, although with but little firmness, less indeed than it exhibited subsequent to its passage through the glands.

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* See Art. "Lymphatic System," loc. cit.

We come now to consider the nature of the contents of the thoracic duct.

These, as already stated, vary according to the condition of the animal; thus, if it be fasting, the duct contains only lymph; if, however, the contents be examined soon after a full meal, they will be found to present nearly all the characters, physical and vital, of the chyle, and in addition, especially in the fluid obtained from the upper part of the duct, a pink hue, said to be deepened by exposure to the air.

This red colour has been noticed by many observers, and it is now generally agreed that it arises from the presence in the fluid of the thoracic duct of numerous red blood corpuscles.

The question is not as to the existence of blood discs in that fluid, but as to the manner in which their presence therein should be accounted for, whether it is to be regarded as primary and essential, or as secondary and accidental.

Most observers agree in considering the presence of blood discs in the chyle of the thoracic duct as accidental, although they account for their existence in it in different ways.

The distinguished Hewson * detected blood corpuscles in the efferent lymphatics of the spleen, which empty their contents into the thoracic duct, and in this way he conceived that the fluid of that vessel acquired its colour.

The accuracy of Hewson's observation, as to the lymphatics of the spleen containing blood corpuscles, is confirmed by Mr. Gulliver, of the fidelity, originality, and number of whose remarks on the microscopic anatomy of the animal fluids it is impossible to speak in terms of too high praise. Mr. Gulliver detected blood corpuscles in the efferent lymphatics of the spleen of the ox and of the horse.

Müller, and MM. Gruby and Delafont, attribute the presence of blood discs in the chyle to the regurgitation of a small quantity of blood from the subclavian vein: if they are really foreign to the chyle, this is the most probable channel of their ingress.

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* Experimental Inquiries, part iii. Edited by Magnus Falkoner. London, 1777, pp. 122. 112. 135.

Mr. Lane thinks that the division of the capillaries, which necessarily takes place in the opening of the duct, allows of the admission into its contents of the blood discs, which are there found. Such are the several ways in which it has been suggested that the blood corpuscles find entrance into the thoracic duct.

Mr. Gulliver has noticed that the blood corpuscles contained in the chyle are usually much smaller than those taken from the heart of the same animal, and also, that not more than one fourth of the entire number present their ordinary disc-like figure, the remainder being irregularly indented on the edges, or granulated. The first of these observations, viz. that which refers to the smaller size of the blood corpuscles found in the chyle, might be explained by supposing that those corpuscles were in progress of formation, and that they had not as yet attained their full development; the other remark, as to the deformed and granulated character of the corpuscles, might be reconciled with the former explanation, by supposing that some time had elapsed between the death of the animal and the examination of the fluid of the thoracic duct. If this manner of accounting for the condition presented by the blood corpuscles of the chyle should be proved to be insufficient, which I myself scarcely think it will, then the only other mode of explaining their appearances is by supposing that their presence in the chyle is really foreign, and that, soon after their entrance into that fluid, the blood corpuscles begin to pass through those changes, indicative of commencing decomposition, of which they are so readily susceptible.

Leaving, however, for the present the question of the origin of the red corpuscles of the blood, which will have to be more fully discussed hereafter, we will in the next place bestow a few reflections upon the origin of the white corpuscles: into this subject, however, it is not intended to enter at any length at present, but merely to make such observations as seem more appropriately to find their place in the chapter on the Chyle and Lymph.

It has been noticed that the white corpuscles occur in very great numbers in the chyle obtained from the mesenteric and lymphatic glands: this observation has led to the supposition that the white corpuscles are formed in those glands.

Upon this question, as upon so many others, Comparative Anatomy throws much light. It has been ascertained that the glands referred to have no existence in the *amphibia* and in *fishes;* in birds, too, they are only found in the neck. Thus it is evident, that the lymphatic glands, however much they may contribute to the formation of the white corpuscles, are not essential to their production.

Corpuscles, very analogous to those of the chyle and the lymph, are found in vast quantities in the fluid of the thymus gland in early life: these corpuscles Hewson considered to be identical with the globules of those fluids, and therefore he regarded the thymus gland as an organ of nutrition, and as an appendage to the lymphatic system. In this opinion he has been followed by Mr. Gulliver. That it is an organ of nutrition, adapted to the special exigencies of early life, there can be no doubt; but that it is an appendage of the lymphatic system, and that the globules with which it so abounds are the same as those of the lymph and chyle, admits of much diversity of opinion.

The globules of the thymus have undoubtedly striking points of resemblance with the corpuscles so frequently alluded to; they have the same granular structure; they are, like them, colourless, and to some extent they comport themselves similarly under the influence of certain re-agents.

There are points, however, of dissimilarity as well as of resemblance; thus they are usually very much smaller than the lymph corpuscles, they do not undergo any increase of size when immersed in water, and acetic acid does not disclose the presence of nuclei.

But above all, the corpuscles of the thymus differ from those of the lymph and chyle in their situation: those of the latter fluids are always *inclosed in vessels* in lymphatics, or lacteal lymphatics; while those of the former fluid, that of the thymus gland, are extravascular, lying loosely in the meshes of the cellular tissue which forms the foundation of the substance of the gland itself.

Now it is impossible to conceive that solid organisms of such a size as the corpuscles of the thymus can enter the lymphatics bodily: —if they are received into the circulation at all, they must first undergo a disintegration and dissolution of their structure.

Both Mr. Gulliver and Mr. Simon * regard the corpuscles of the thymus as cytoblasts; the former, however, believes that before their development as cytoblasts they enter the circulation, while the other conceives that they are developed in the gland itself into true nucleated cells.

It is difficult to suppose with Mr. Simon, that the small and uniform granular corpuscles of the thymus are developed into the large, complex, and curiously constituted true secreting cells of that gland.

Whether this be the case or not, however, it would appear that Mr. Simon has fallen into a certain amount of error in his account of the structure of the thymus gland, and also of other analogous glands, as well as in the generalisations deduced by him therefrom.

Thus Mr. Simon states, that in early life there exists in the thymus gland "no trace whatever of complete cells;" that it is only in later life that nucleated cells are formed, and that these are developed out of the granular corpuscles already referred to, and which are alone present in the gland in the first years of its existence. The same statements are applied to the thyroid body.

But Mr. Simon does not rest here: he regards the long persistence of the corpuscles, which he states are to be found in all those glands which secrete into closed cavities, in the condition of cytoblasts, as constituting a remarkable and important distinction between the glands in question and the true secreting glands which are furnished with excretory ducts.

These observations are to a considerable extent erroneous, as is proved by the fact that true nucleated cells *are to be met*

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* Prize Essay on the Thymus Gland. London, 4to, 1846.

with abundantly in the thymus gland of still-born children, and also in the thyroid body and supra-renal capsule; in the last, indeed, almost every cell is nucleated.

On this supposed essential structural distinction between the true glands which are furnished with excretory ducts, and those anomalous ones which are destitute of such ducts, Mr. Simon founds some general deductions.

It is known that the functions performed by the glands without ducts are of a periodic and temporary character, while those discharged by the true glands are of a permanent and constant nature.

It is also considered by some physiologists that the nucleus of every nucleated cell is the only true and necessary secreting structure.

These views of the nature of the functions performed by the anomalous glands, and of the importance of the nucleus, being adopted by Mr. Simon, he thence draws the inference that the cytoblastic condition of the cells of the thyroid, thymus, and other analogous glands, is precisely that which is required by organs which are called only into action periodically, and in which great activity prevails at certain periods.

This theory is ingenious, but it has been seen that the main fact upon which it rests is for the most part erroneous, and the basis of the theory being removed, the theory itself must fall.

In order that it may be seen that the opinions entertained by Mr. Simon, in his Essay on the Thymus, have not been overstated, I will introduce a few passages therefrom:—

"Thus while the completion of cells, within the cavities of the thyroid gland, is assuredly *a departure* from the habitual state of that organ, and probably the evidence of protracted activity therein; it is yet just such a direction as may serve even better than uniformity to illustrate the meaning of the structures which present it; for it shows, beyond dispute, that the dotted corpuscles are homologous with the cytoblasts of true glands." (p. 79.)

"In the thymus one would at first believe a similar low stage of cell development to be universal; for in examining the contents of the gland in early life, one finds *no trace whatever of complete cells.* The dotted corpuscles are undoubtedly quite similar to those which we have recognised as becoming the nuclei of cells in the thyroid body, and in other organs; there is abundant room for conjecturing them to be of a correspondent function — to be, in fact, true cytoblasts; but the arguments for this point cannot be considered quite conclusive, without some additional evidence."

"The *completion* of a cell, from the isolation of so much of the secreted product as is collected round each cytoblast, is a very frequent secondary process. In the true glands it is very frequent, *in those without ducts exceptional,*" (p. 84.)

With one other remark on the corpuscles of the thymus, we will conclude this short chapter: mixed up with those corpuscles are frequently to be noticed many nucleated globules, in every way similar to the white corpuscles of the blood, but very distinct from the true cell corpuscles of the gland; the nucleus of these white globules is of nearly the same size as the dotted corpuscles themselves. Is there any relation between this coincidence in size?

We now pass to the consideration of the most important fluid in the animal economy, viz. the blood.*

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* Plate VIII. will contain figures illustrative of the chyle.

ART. II. THE BLOOD.

Of all the fluids in the animal economy, the most interesting and the most important is the Blood: and it is an appreciation of this fact which has led to the concentration upon its study, in times past as well as present, of the powers of a host of able and gifted observers, whose labours have not been without their reward.

The knowledge of this fluid acquired by the early physician was of a very limited character, it being confined to the observance of a certain number of external and obvious appearances, such as the colour, consistence, and form of the effused blood. Limited as this knowledge was, however, compared with that which, in our favoured day, we enjoy, it was yet not without its practical utility.

More recently the chemist, who is in these times extending in all directions so rapidly the boundaries of his domain, has cast upon this particular portion of it a flood of light. Who, to look upon a dark and discoloured mass of blood, could imagine that the magic power of chemistry could reveal in it the existence of not less than forty distinct and essential substances?

Lastly, the micrographer, with zeal unweariable, has even outstripped the progress of his rival the chemist, and brought to light results of the highest importance. It is these results that in this work we have more especially to consider.

In the following pages we shall have to treat of the blood under various aspects and conditions; we shall have to regard it alive and dead, circulating within its vessels, and motionless without them; as a fluid and as a solid; healthy and diseased; or, in other words, we shall have to consider the blood physiologically, pathologically, and anatomically.

DEFINITION.

The blood may be defined as an elaborated fluid, having usually a specific gravity of about 1·055, that is, heavier than water; in mammalia and most vertebrate animals, being of a red colour, but colourless in the invertebrata*; circulating in distinct sets of vessels, arteries, and veins; holding in solution, all the elements of the animal fabric—fibrin, albumen, and serum, together with various salts and bases, and in suspension, myriads of solid particles termed globules.†

The blood would thus appear to be the grand supporter and regenerator of the system; in early life, supplying the materials necessary for the development of the frame, and, in adult existence, furnishing those required for its maintenance: hence "the blood" has been figuratively called "the life."

COAGULATION OF THE BLOOD, WITHOUT THE BODY.

The first change which the blood undergoes subsequent to its removal from the body consists in its coagulation. This phenomenon has been denominated emphatically "the death of the blood," because, when it has once occurred, the blood is thereby rendered unfit to maintain the vital functions, and there is no known power which can restore to it that faculty.

Although the word coagulation is usually applied generally to the blood, yet it is not to be understood that the whole of the mass of that fluid undergoes the change of condition implied by the term coagulation, which affects but a single element of the blood,—viz. the fibrin.

The precise circumstances to which the coagulation of the blood is due, have never as yet been satisfactorily explained and determined. Some have conceived that it resulted from the escape of a vital air or essence. Much has been said and written upon this "vital principle," and, it seems to me, with very little profit. It would be more philosophical, I think, to regard animal life not as an essence, or ether, but as the complex operation of nicely adjusted scientific adaptations and principles. According to this view, the human frame in health would be comparable (and yet, withal, how incomparable is it!) to a finely-balanced machine, in which action and reaction are proportionate, and in disease disproportionate, the injury to the machine being equivalent to the disproportion between the two forces. *

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* Müller states that the quantity of blood in the system varies from eight to thirty pounds, and Valentin found that the mean quantity of blood in the male adult, at the time when the weight of the body is greatest, viz. at thirty years, is about thirty-four and a half pounds, and in the adult female, at fifty years, when the weight of the body in that sex is at its maximum, about twenty-six pounds. According also to Müller, the specific gravity of the blood varies from 1·527 to 1·057; arterial blood is lighter than venous.

† In one vertebrate animal, a fish, *Branchiostoma lubricum* Costa, the blood is colourless, and in the most of *Annelidæ* it is red; the red colour, however, exists in the *liquor sanguinis*, and not in the blood corpuscles.

The coagulation of the blood, in some degree, doubtless depends upon the operation of the following causes, each contributing in a greater or lesser degree to the result; namely, the cessation of nervous influence, the abstraction of caloric, the exercise of chemical affinity between the particles of fibrin, and, lastly, a state of rest: between motion and life a very close connexion appears to exist. †

Formation of the Clot.

A portion of blood having been abstracted from the system, and allowed to remain for a few minutes in a state of quiescence, in a basin or other suitable vessel, soon manifests a change of condition. This consists in the separation of the fibrin and globules of the blood, which go to form the clot, from the serum, which holds in solution the various salts of the blood. In this way a rude and natural analysis is brought about; the fibrin, being heavier than the serum, falls to the bottom, and, by reason of its coherence and contractility, forms a compact mass or clot, the diameter of which is less than that of the vessel in which it is contained; while the lighter serum floats on the top and in the space around the clot.

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* It is hoped that the preceding brief remarks will not expose the writer to the charge of being a Materialist; between animal life and mind an essential distinction exists.

† "Fresh blood if exposed to a very low temperature freezes, and may in that state be preserved, so as to be still susceptible of coagulation when thawed."—MÜLLER.

Now the only active agent in this change in the arrangement of the different constituents of the blood, is the fibrin; and although the globules of the blood constitute a portion of the clot, yet they take no direct part in its formation, and their presence in it is thus accounted for; the fibrin, in coagulating, assumes a filamentous and reticular structure, in the meshes of which the globules become entangled, and thus are made to contribute to the composition of the clot, the bulk of which they increase, and to which they impart the red colour.

It was an ancient theory that the clot was formed solely by the union of the globules with each other. The fallacy of this opinion is easily demonstrated by the two following decisive experiments:—

The first is that of Müller, on the blood of the frog, who separated, by means of a filter, the globules from the fibrin, the latter still forming a clot, although deprived of the globules. This experiment is not, however, applicable to the blood of man, or of mammalia in general, the globules in these being too small to be retained by the filter. The second expedient is, however, perfectly suited to the human blood. It is well known that if blood, immediately after its removal from the body, be stirred with a stick, the fibrin will adhere to it in the form of shreds: the blood being defibrinated by this means, the globules fall to the bottom of the basin in which the blood is contained, on account of their gravity; but they do not cohere so as to form a clot, remaining disconnected and loose.

It is difficult to determine the exact time which the blood takes to coagulate, because this coagulation is not the work of a moment; but, from its commencement to its completion, the process occupies usually several minutes. The first evidence of the formation of the clot, is the appearance of a thin and greenish serum on the surface of the blood, in which may be seen numerous delicate fibres, the arrangement of which may be compared to that of the needle-like crystals contained in the solution of a salt in which crystallisation has commenced. Estimating, however, the coagulation neither from its commencement nor from the complete formation and consolidation of the clot, but from the mean time between these two points, it will generally be found that healthy blood coagulates in from fifteen to twenty minutes.

In diseased states of the system, however, the time occupied in the coagulation of the blood, or, in other words, in the formation of the crassamentum, or clot, varies very considerably; and it is of much practical importance that the principle which regulates this diversity should be clearly understood.

In disorders of an acute, active, or sthenic character, in which the vital energies may be regarded as in excess, as, for instance, in inflammatory affections, in pneumonia, pleurisy, acute rheumatism, and sanguineous apoplexy: in febrile states of the system, as in the commencement of some fevers, as in ague, plethora, and as in utero-gestation, the blood takes a much longer time than ordinary to coagulate, no traces of this change in the passage of the blood from a fluid to a solid state being apparent until from sixteen to twenty minutes have elapsed. This length of time may be accounted for, by supposing that, in the affections named, the blood is endowed with a higher degree of vitality, and that therefore a longer period is required for its death to ensue; or, in other words, if the expression may be allowed, that the blood in such cases dies hard. On the contrary, in disorders of a chronic, passive, or asthenic character, in all of which there is deficiency of the vital powers, as in typhus, anemia, chlorosis, the blood passes to a solid state in a much shorter period than ordinary, even in from five to ten minutes. In these cases the vitality of the blood is very feeble, and it may be said to die easily. A remarkable difference is likewise observable in the characters of the clot formed in the two classes of disorders named; in the first it is firm, and well defined; in the second, soft, and diffluent.* To this subject we shall have occasion again to refer, more at length.

Fibrin, if left at rest for a time, undergoes a softening process, and breaks up into an extremely minute granular substance. This softening of the fibrin has been improperly confounded with suppuration; the softened mass, however, may be distinguished from true pus by the almost complete absence of pus globules. This peculiar change in the condition of the fibrin has been noticed to occur both in blood contained within and without the body, and large softened clots of it are not unfrequently encountered in the heart after death. The process always commences in the centre of these clots.

Formation of the Buffy Coat of the Blood.

Surmounting the coloured portion of the clot is observed, in blood taken from the system in inflammatory states, a yellowish green stratum: this constitutes the buffy or inflammatory crust, the presence of which was deemed of so much importance by the ancient physician, and which is indeed not without its pathological value. This crust consists of fibrin deprived of the red globules of the blood; and its mode of formation is thus easily and satisfactorily explained. Of the constituents of the blood, the red globules are the heaviest: now, supposing that no solidification of any one element were to take place, these, of course, would always be found occupying the lowest position in the containing vessel; the fibrin would take the second rank, and the serum the third: but such, under ordinary circumstances, not being the case, and the fibrin coagulating so speedily, the globules become entangled in its meshes before they have had sufficient time given them to enable them to obey fully the impulse derived from their greater specific gravity; and thus no crust is formed. In blood drawn in inflammations, however, this coagulation, as already stated, proceeds much more slowly; and thus time is allowed to the globules to follow this impulse of the law of gravity to such an extent, as that they fall a certain distance, about the sixteenth of an inch, usually, below the surface of the fibrin before its complete coagulation averts their further progress; and a portion of which is thus left colourless, which constitutes the buffy and so called inflammatory crust of the blood. But there are other considerations to which it is necessary to attend, and which contribute to the formation of the buffy coat.

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* It is to be remarked, that the clot is not of equal density throughout, but that its lower portion is invariably softer than the upper, and this is accounted for by the fact of its containing less fibrin.

One of these is the greater relative amount of fibrin which inflammatory blood contains.

A second is the increased disposition, first pointed out by Professor Nasse, which the red corpuscles have in inflammatory blood to adhere together and to form rolls, and the consequence of which is that they occupy less space in the clot.

A third additional consideration, to which it is necessary to attend, in reference to the formation of the inflammatory crust, is the density of the blood, which bears no exact relation to the amount of fibrin, but depends rather upon the quantity of albumen which it contains.* The greater the density of the blood, the longer would the globules take to subside in that fluid; and the less its density, the shorter would that period be. Now inflammatory blood is usually of high density, while with that of feeble vitality, the reverse obtains. Thus were it not for the fact, that in blood in the first state, coagulation is slow, and in the second quick, the blood of weak vital power would be that in which, *à priori*, we should expect to see the buffy coat most frequently formed; but the much greater rapidity in the coagulation of the blood more than counterbalances the effect of density.

The blood, then, may be so dense, that although at the same time it coagulates very slowly, yet no inflammatory crust be formed, the patient from whom the blood is extracted labouring all the while under severe inflammation. An ignorance of this fact has been the source of many great and perhaps fatal errors, on the part of those physicians who have been used to regard the presence of the buffy coat as an undoubted evidence of the existence of inflammation, and its absence as indicating immunity therefrom. It has been remarked that, in the first bleedings of pneumonic patients, the blood often wants the buffy coat: this is attributed to its greater density, and which is found to diminish with each succeeding abstraction of blood; so that if inflammation be present, the characteristic coat is usually apparent also after the second bleeding.

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* It has been remarked, that in albuminuria, in which a considerable portion of the albumen of the system passes off with the urine, the blood possesses a very feeble density.

The conditions, then, favourable to the formation of the buffy coat, are a mean density of the blood, slow coagulation; excess of fibrin, and increased disposition to adherence on the part of the red corpuscles.

Other circumstances doubtless exist, which in a minor degree affect the formation of the crust: such as the density of the globules, and the qualities of the fibrin itself. Into these it is unnecessary to enter, as they do not vitiate the accuracy of the general statements.

The Cupping of the Clot.

At the same time that the crassamentum exhibits the buffy coat, the upper surface of the clot is very generally also cupped. This cupping of the clot arises from the contraction of that portion of the fibrin which constitutes the buffy stratum, and which contraction operates with greater force on account of the absence in it of the red corpuscles of the blood. The degree to which the clot is cupped, therefore, probably is in direct relation with the thickness of the crust. Its presence was also regarded as an indication of the existence of inflammation, the amount of cupping denoting the extent of inflammation. This sign is not, however, any more than that afforded by the buffy coat, to be considered as an invariable criterion of the existence of inflammation.*

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* Professor Nasse has pointed out a mottled appearance which is

COAGULATION OF THE BLOOD, IN THE VESSELS, AFTER DEATH.

The coagulation, or death, which we have described as occurring in blood abstracted from the system by venesection, takes place likewise, — the vital influence which maintains the circulation being removed, — in that which is still contained within the vessels of the body, although in a manner less marked and appreciable.

As also in the case of the blood withdrawn from the system, the time occupied in the coagulation of that which is still enclosed in its own proper vessels, varies very considerably. This difference depends partly upon the circumstances under which the patient has died, whether he has been exhausted or not by a previous long and wasting illness, and partly upon temperature and, perhaps, certain electric states of the atmosphere. In all instances, however, a much longer period is required for the production of coagulation in blood not removed from the body, than in that which has been withdrawn by bleeding; this change in its condition being seldom effected, in the former instance, in a shorter period than from twelve to twenty-four hours subsequent to decease; although occasionally, but rarely, it may occur at periods either earlier or later than those named.

Signs of Death. — It has already been stated, that blood once coagulated is rendered unfit for the purposes of life, and that no known means exist capable of restoring to coagulated blood its fluid state, so as to render it once again

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frequently observed to precede the formation of the buffy coat, and the existence of which he states to be quite characteristic of inflammatory blood. This appearance is produced in the following manner: after the lapse of a minute or two a peculiar heaving motion of the threads or rolls formed by the union of the red corpuscles with each other is observed to take place; this results in the breaking up of the rolls, the corpuscles of which now collect into masses, leaving, however, intervals between them, and which become filled with fibrin; now it is the contrast in colour between this fibrin and the masses of red corpuscles which occasions the blood in coagulating to assume the mottled aspect referred to.

suited to play its part in the maintenance of the vital functions. The accuracy of these statements is attested by physiology, which demonstrates to us that a fluid condition is necessary to the blood, for the correct performance of its allotted functions. It follows, then, from the foregoing, that a coagulated state of the blood, not in a single vessel indeed, but in the vessels of the system generally, affords a certain indication that death has occurred, and that therefore a return to life has become impossible.

It has ever been an object of the highest importance to distinguish real from apparent death; and anxious searches have been instituted in the hope of discovering some certain sign whereby the occurrence of death is at once signalised. Hitherto this inquiry has been unsuccessful; and it could hardly have been otherwise; for before the physiologist will be able to determine the precise moment when life ceases, and death begins, he must know in what the life consists, for death is but the negation of life. It is probable that the mystery of life will never be revealed to man; if, indeed, it be any thing more than, as already hinted, the result of the combined operation of various chemical and physical laws appertaining to matter.

Although no one single sign has hitherto been discovered indicative of death at the moment of its occurrence, yet several appearances have been remarked some time after death, all of which are of more or less value in determining so important a point. Independently of the cessation of respiration and circulation, the presence of muscular rigidity, some other changes have been noticed to occur in different parts of the human body soon after the extinction of life; as, for instance, in the eye, and in the skin: these are mostly, however, symptomatic of incipient decomposition, and the time of their accession is very uncertain: they likewise affect parts, the integrity of which is not essential to life. A fluid state of the blood, on the contrary, has been shown to be indispensable to life; so that the change which it undergoes in the vessels of the body so quickly after death, may be employed with much advantage and certainty in determining, in doubtful cases, whether life has become extinct or not.

It is by no means difficult to establish the fact of the coagulation of the blood in the vessels after death. If a vein be opened, as in the ordinary operation of bleeding, in a person who has just died, the blood will issue in a fluid state, as in life; but it will not leap forth in a stream. If a little of the blood, thus procured, be preserved in a small glass, we shall soon remark the occurrence of coagulation in it, from which we shall know that the fibrin within the vessels has not as yet assumed a solid form. If we repeat this operation at the end of about eighteen hours, we shall obtain only a small quantity of reddish serum, in which, on being set aside for a time, no crassamentum will be found, the only change occurring in this serum consisting in the subsidence of the few red globules which were previously suspended in it, and which now form, at the bottom of the glass, a loose and powdery mass. By this experiment, which may be repeated on several veins, and even on an artery, we have clearly established the fact of the coagulation of the blood within the vessels of the body, and therefore have ascertained, in a manner the most satisfactory, that life is extinct.

In some instances, the blood is said to remain fluid after death: this statement is not strictly correct, as a careful examination of such blood will always lead to the detection of some traces of coagulation. To the subject of the fluid condition of the blood after death, we shall have hereafter to return, in treating of the pathology of the blood.

When it is recollected that the heat of some climates, and the laws and usages of other countries, compel the interment of the dead a very few hours after decease, the importance of this inquiry will become apparent; and the value of any sign which more certainly indicates death than those usually relied upon in determining this question, will be more fully appreciated.

It cannot be doubted but that, from the insufficient nature of the signs of death usually regarded as decisive, premature interment does occasionally take place; and it is probable that this occurrence is far less unfrequent than is generally supposed, and that for each discovered case, a hundred occur in which the fatal mistake is never brought to light, it being buried with the victim of either ignorance or carelessness.*

We have now to proceed to the anatomical consideration of the blood: we have to pass to the description of the solid constituents of that fluid, the globules; to describe their different kinds, their form, their dimensions and their structure; their origin, their development, and their destination their properties, and their uses.

THE GLOBULES OF THE BLOOD.

The blood is not an homogeneous fluid, but holds in suspension throughout its substance a number of solid particles, termed globules. These serve to indicate to the eye the motion of the blood; and were it not for their presence, we should be unable to establish, microscopically, the fact of the existence of a circulation, to mark its course, and to estimate the relative speed of the current in arteries and veins under different circumstances.

These globules are so abundant in the blood, that a single drop contains very many thousands of them, and yet they are not so minute but that their form, size, and structure, with good microscopes, can be clearly ascertained and defined. They are not all of one kind, but three different descriptions have been detected—the red globules, the white, and certain smaller particles, termed molecules. We shall take each of them in order; and notice, in the first place, the red globules.†

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* The coagulation of the blood may be retarded or altogether prevented by its admixture with various saline matters: to this point we shall have occasion to refer more fully hereafter.

† Malpighi first signalised the existence of the red globules in the blood, so far back as 1665: he regarded them as of an oily nature. The words in which this discovery was recorded were as follow:—"Sanguineum nempe vas in omento hystricis . . . in quo globuli pinguedinis propriâ figurâ terminati rubescentes et corallorum rubrorum vulgo coronam

THE RED GLOBULES.

The number of red globules existing in the blood surpasses by many times that of the white. To the sight, when seen circulating in this fluid, they appear to constitute almost the entire of its bulk. We shall now have to consider their form, the size, the structure, and the properties by which they are characterised.

Form.—In man, and in most mammalia, the red blood corpuscles are of a circular but flattened form, with rounded edges, and a central depression on each surface, the depth of which varies according to the amount of the contents of each globule.* Such is the normal form of the blood discs, or the shape proper to them while circulating in the blood of an adult. (See Plate I. *fig.* 1.) In that of the embryo, the depression is wanting, and the globules are simply lenticular.†

The blood globules, however, like all minute vesicles, possess the properties of endosmosis and exosmosis. These principles depend for their operation upon the different relative density of two fluids, the one external to the vesicle, the other internal. When these two fluids are of equal density, then no change in the normal form of the vesicles occurs: when, however, the internal fluid is of greater density than the external, then an alteration of shape does take place; endosmosis ensues, in which phenomenon a portion of the liquid without the vesicle passes through its

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æmulantes . . ."—De Omento et adiposis Ductibus. Opera omnia. Lond. 1686.

Leeuwenhoek was, however, the first observer who distinctly described the blood globules in the different classes of animals: this he did in 1673. These historical reminiscences are not without their interest, and further references of this kind will be introduced in the course of the work.

* The central depression was first noticed by Dr. Young. The flattened form with the central depression on each surface, and of which a bi-concave lens would form an apt illustration, is that which any vesicle partially emptied of its contents would assume.

† Hewson figured the difference in the form of the blood globule in the embryo, and in the adult, in the common domestic fowl, and in the viper.

investing membrane, and thus distends and modifies its form. Lastly, when a reverse disposition of the fluids exists, a contrary effect becomes manifested; exosmosis is the result; which implies the escape of a portion of the contents of the vesicle into the medium which surrounds and envelopes it. The operation of these principles are beautifully seen, not merely in the blood globules, but more especially in those exquisitely delicate formations, the pollen granules.

Between the density of the liquid contained within the red globules, and that of the *liquor sanguinis,* in states of health, a nice adaptation or harmony exists, whereby these globules are enabled to retain their peculiar form. There is, however, scarcely any other fluid which can be applied to the globules which does not, more or less, affect their shape, most of the reagents employed in their examination rendering them spherical. (See Plate I. *fig.* 3.)

From the preceding observations, therefore, it follows that the red globules, to be seen in their normal condition, should be examined while still floating in the serum: they are best obtained by pricking the finger with a needle or lancet.

Usually, when the microscope is brought to bear upon the object-glass, the globules are seen to be scattered irregularly over its surface, the majority of them presenting their entire disc to view, others lying obliquely, so as to render apparent the central depression, and others again exhibiting their thin edges. (See Plate I. *fig.* 1.) Not unfrequently, however, a number of corpuscles unite together by their flat surfaces, so as to form little threads, comparable to strings of beads, or of coins, which are more or less curved, and in which the lines of junction between the corpuscles are plainly visible. These strings of compressed globules bear also a close resemblance to an *Oscillatoria,* and a still closer likeness to the plant described in the history of the British Freshwater Algæ, under the name of *Hæmatococcus Hookeriana.* (See Plate I. *fig.* 4.) The cause which determines this union of the cells still requires to be explained, and would seem to be referable to a mutual attraction exerted by the globules on each other. Andral asserts that when the fibrin of the blood is abstracted, they do not thus cohere. Professor Nasse, as already remarked, states that this disposition on the part of the red corpuscles to unite together and form rolls (as of miniature money in appearance), is increased in inflammatory blood. The union does not, however, last long; a heaving to and fro of the strings of corpuscles soon taking place, and which terminates in their disruption.[*]

Size.—The size of the red corpuscles of the blood, although more uniform than that of the white, is nevertheless subject to considerable variation. Thus, the globules contained in a single drop of blood are not all of the same dimensions, but vary much. These variations are, however, confined within certain limits: the usual measurement in the human subject is estimated at about the $\frac{1}{3500}$ of an inch; but, occasionally, globules are met with not exceeding the $\frac{1}{4545}$; and, again, others are encountered of the magnitude of the $\frac{1}{3279}$ of an inch: these are, however, the extreme sizes which present themselves.[†] The difference in the size of the red corpuscles, which has been indicated, is a character common to them in the blood of all persons, and at every age. Another variation as to size exists, which is, that the corpuscles are larger in the embryonic and fœtal than they are in adult existence.* This observation is important, inasmuch as it seems to prove that the blood does not pass directly from the maternal system into the fœtal circulation, but that the corpuscles are formed independently in the fœtus. In states of disease, also, it has been remarked by Mr. Gulliver that there is even a still greater want of uniformity in the measurements presented by the red corpuscles.

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[*] In reptiles, birds, and fishes, the red globules are elliptical, a form possessed also by some few *mammalia*, chiefly of the family *Camelidæ*. This fact was first discovered by Mandl, in the dromedary and paco; and subsequently by Gulliver, in the vicugna and llama. The oval globules of these animals, however, could not be confounded with those of reptiles, birds, and fishes, than the corpuscles of which they are so much smaller, and, further, are destitute of the central nucleus, which characterises the blood globules of all the *vertebrata*, the *mammalia* alone excepted. The long diameter of the blood corpuscles of the dromedary, Mr. Gulliver states to be the $\frac{1}{3254}$ of an inch, and its short the $\frac{1}{5921}$; the first of these measurements exceeds but little the diameter of the human blood corpuscles.

Amongst fishes one exception to the usual oval form of the blood corpuscle has been met with: this occurs in the lamprey, the blood disc of which Professor Rudolph Wagner observed to be circular; in form then the blood corpuscle of the lamprey agrees with that of the mammalia, but in the presence of a nucleus, the existence of which has been recently ascertained by Mr. T. W. Jones, it corresponds with the structure of the blood discs of other fishes.

[†] The first measurement given is that which is usually adopted by writers; the last two are those made by Mr. Bowerbank for Mr. Owen, and which are to be found in the latter gentleman's paper on the Comparative Anatomy of the Blood Discs, inserted in the Lond. Med. Gazette

A careful examination of the elaborate tables of Mr. Gulliver on the measurements of the blood corpuscles, appended to the translation of Gerber's Minute Anatomy, tends to show that a general, though not a very close or uniform relation, exists between the size of the blood corpuscles amongst the mammalia, and that of the animal from which they proceed. These tables furnish more evidence in favour of this co-relation than they do in support of the assertion that has been made, that the dimensions of the corpuscle depend upon the nature of the food. It would appear, however, nevertheless, that the corpuscles of *omnivora* are usually larger than those of *carnivora*, and these, again, larger than those of *herbivora*.† In a perfectly natural family

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for 1839. The measurements which I have made of the human blood corpuscle do not accord with those which are generally regarded as correct: thus I find the average diameter of the blood globule of man to be, when examined in the serum of the blood, about the $\frac{1}{2800}$ of an inch, and in water in which the corpuscles are smaller, as a necessary consequence of the change of form, the $\frac{1}{3600}$. The micrometer employed by me is a glass one, precisely similar to that made use of by Mr. Gulliver, being furnished to me by the same eminent optician, Mr. Ross, from whom his own was obtained.

* This is the opinion of Hewson, Prevost, and Gulliver, and I have myself to some extent confirmed its accuracy.

† The largest globules which have as yet been discovered, are those of the elephant; the next in size, those of the capybara and rhinoceros; the smallest, according to the observations of Mr. Gulliver, are those of the napu musk-deer. The corpuscles of the blood of the goat were formerly con-

of *mammalia*, as the rodents or the ruminants, there is also an obvious relation between the size of the corpuscle and that of the animal.

Gerber states that there is an exact relation between the size of the blood globules and that of the smallest capillaries. This observation is doubtless strictly correct.

Structure.—Much diversity of opinion has, until recently, prevailed, and does still obtain, although to a less extent, in reference to the intimate structure of the red globule. This diversity has arisen partly from the imperfections of the earlier microscopic instruments employed in the investigation, and in part is due to the different circumstances in which observers have examined the blood corpuscle. Thus, one micrographer would make his observations upon it in one fluid, and another in some other medium, opposite results and conclusions not unfrequently being the results of such uncertain proceedings. These discrepancies it will be the writer's endeavour, as far as possible, to reconcile with each other, as well as to point out those observations which are entitled to our implicit belief, and those which yet require confirmation. This being done, we shall be in a position to form some certain conclusions. The earlier microscopic observers believed, almost without exception, in the existence of a nucleus in the centre of each blood corpuscle. Into this belief they were no doubt led more from analogy than from actual observation. Now analogy, although frequently useful in the elucidation of obscure points, affords in the present instance but negative and uncertain evidence. In the elliptical blood discs of reptiles, birds, and fishes, a solid granular nucleus does undoubtedly exist; but the best optical instruments, in the hands of the most skilful recent micro-

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sidered to be the smallest. The following are the dimensions given by Mr. Gulliver of some of the animals above named. Diameter of corpuscle of the elephant, the $\frac{1}{2745}$ of an inch; of capybara, the $\frac{1}{3216}$; of goat, the $\frac{1}{6366}$; and of napu musk-deer $\frac{1}{12325}$. The white corpuscles of the musk-deer are as large as those of a man; a proof that the red corpuscles are not formed, as many suppose, out of the colourless blood globules. (See the figs.)

graphers, aided by the application of a variety of re-agents, have failed, utterly, in detecting the presence of a similar structure in the blood globule of the human subject in particular, and of mammalia in general. I therefore do not hesitate to join my opinion to that of those observers who deny the existence of a nucleus in the blood discs of man and mammalia.*

The appearance of a nucleus is, indeed, occasionally presented; but this appearance has been wrongly interpreted. An internal small ring, under favourable circumstances, may be seen in the centre of each blood corpuscle: this ring is occasioned by the central depression, the outer margin of which it describes; and it was the observance of it that gave to Della Torre the erroneous impression, that each globule had a central perforation, and therefore was of an annular form; and further, probably induced Dr. Martin Barry to describe it as a fibre.

The very existence, on both surfaces of the blood disc, of a deep central depression, together with its little thickness, almost preclude the possibility of the presence of a nucleus.

An endeavour to account for the absence of a nucleus in the blood corpuscle of the human adult has been made by supposing that it does really exist in the blood of the embryo. The answer to this supposition is, that no nucleus is to be found in embryonic blood, and that if it were, it would be no reason why the nucleus should not also be met with in the blood of the adult, seeing that the blood disc is not a permanent structure, as an eye or a limb, but one which is perpetually subject to destruction and renewal.

Having then arrived at the conclusion that no nucleus exists in the blood corpuscle of man, we have now to ask ourselves the question, what, then, is really the constitution of the red blood globule?

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* Amongst those who have asserted their belief in the presence of a nucleus, may be mentioned Hewson, Müller, Gerber, Mandl, Barry, Wagner, Rees, Lane, and Addison; and of those who have held a contrary opinion, Majendie, Hodgkin, Liston, Young, Quekett, Gulliver, Lambotte, Owen, and Donnè.

Some observers have compared it to a vesicle. This definition does not seem to be altogether satisfactory; for although each corpuscle possesses the endosmotic properties common to a vesicle, no membrane, apart from the general substance of the globule, (I speak more particularly of the human blood disc,) has been demonstrated as belonging to it.

Each globule in man may therefore be defined to be an organism of a definite form and homogeneous structure, composed chiefly of the proteine compound *globuline*, which resembles albumen very closely in its properties; its substance externally being more dense than internally, it being endowed with great plastic properties, and, finally, being the seat of the colouring matter of the blood.

The extent to which the red globule is capable of altering its form, is truly remarkable. If it be observed during circulation, it will be seen to undergo an endless variety of shapes, by which it accommodates itself to the space through which it has to traverse, and to the pressure of the surrounding globules. The form thus impressed upon it is not however permanent, for as soon as the pressure is removed, it again instantaneously resumes its normal proportions. On the field of the microscope, however, the corpuscles may be so far put out of form, as to be incapable of restoration to their original shape.

Some observers have assigned to the red globule a compound cellular structure, comparing it to a mulberry. It need scarcely be said that such a structure does not really belong to it. A puckered or irregular outline is not unfrequently presented by many globules: this is due sometimes to evaporation, and then arises from the presence around the margin of the disc, and occasionally over the whole surface, of minute bubbles of air*; and at other times it is the result of commencing decomposition, or the application of some special re-agent, as a solution of salt, in which cases a true change in the form, but not in the structure of the globule, does really occur; its outline becomes irregular, and the surface presents numerous short and obtuse points or spines.* Globules in this state bear some resemblance to the pollen granules of the order *Compositæ.*† (See Plate I. *fig.* 5.)

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* This vesiculated appearance of the blood corpuscles may be produced at once by pressure.

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* Mr. Wharton Jones says, "the granulated appearance" seems to be owing to a contraction of the inner and a wrinkling of the outer of the two layers of which he conceives the wall of the corpuscle to be formed.

† The opinions promulgated by some observers in reference to the intimate structure of the blood corpuscle are singular, and are rendered interesting mainly by reason of the ingenuity of the views expressed. Mr. Addison remarks[1], "Blood corpuscles, therefore, appear to consist of two elastic vesicles, one within the other, and to possess the following structure, 1st, an external and highly elastic tunic, forming the outer vesicle; 2nd, an inner elastic tunic forming the interior vesicle; 3rd, a coloured matter occupying the space between the two tunics; and 4th, a peculiar matter forming the central portion of the corpuscle." Mr. Wharton Jones[2] ascribes a somewhat similar constitution to the blood corpuscle. "The thick wall of the red corpuscle," he says, "consists of two layers. The outer is transparent, colourless, structureless, and resisting, and constitutes about one half of the whole thickness of the wall. The inner layer is softer and less resisting; and is that which is the seat of the colouring matter. Dr. G. O. Rees and Mr. Lane[3] describe the blood corpuscle as containing a fluid and provided with a nucleus composed of a thin and colourless substance. The views of Dr. Martin Barry are, however, the most peculiar of any ever yet published in reference to the blood corpuscle; when first they were announced in the pages of the Philosophical Transactions, the scientific world were taken by surprise and wonderment. Microscopes which had long been suffered to remain undisturbed on their shelves were immediately had recourse to, and many scientific men who previously had never employed the instrument in their investigations, were induced to procure it, in order that they might themselves bear ocular witness of the astonishing facts related by Dr. Barry in reference to blood corpuscles. A short abstract of Dr. Barry's views will be read by some with interest. Dr. Barry considers, that the molecules, the red corpuscles, and the white globules, are different states of the developement of the same structure, the true blood globule. (This is also the opinion of Addison and Donnè.) The first he denominates a "disc," and the last a "parent

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[1] Experimental Researches, pp. 236, 237. Transactions of Prov. Med. and Surg. Association.

[2] See British and Foreign Medical Review, No. xxviii.

[3] Guy's Hospital Reports, 1840.

Colour. — The *hæmatine,* or colouring matter of the blood, seems in the red corpuscle of the mammalia to be diffused generally throughout its substance; in the oviparous vertebrata, however, it is confined to that portion of each corpuscle

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cell." These different stages in the developement of the blood globule, Dr. Barry compares with similar conditions of the germinal vesicle of the ovum. "The disc," he says, "is the most primitive object we are acquainted with;" that it is synonymous with the "nucleus" of most authors and the "basin-shaped granules" of Vogel; that it "contains a cavity, or depression," "the nucleolus," which "is the situation of the future orifice," which he says, the blood corpuscle in certain states exhibits, and "by means of which there is a communication between the exterior of the corpuscle and the cavity in its nucleus;" lastly, the disc is regenerated by fissiparous divisions. These discs are also denominated, "primitive discs," "foundations of future cells." The "parent cells" he conceives to be made up of an assemblage of these discs. Again, Dr. Barry states, "The nuclei of the blood corpuscles furnish themselves with cilia, revolve, and perform locomotion;" "the primitive discs exhibit an inherent contractile power." And of the corpuscles themselves, he remarks, "Molecular motions are discernible within the corpuscles of the blood,"— "changes of form are observed under peculiar circumstances in the corpuscles of the blood." These are, however, only the beginning of wonders related. Dr. Barry elsewhere goes on to observe: "In the mature blood corpuscle (red-blood disc), there is often to be seen a flat filament or band already formed within the corpuscle. In Mammalia, including man, this filament is frequently annular; sometimes the ring is divided at a certain part, and sometimes one extremity overlaps the other. In birds and amphibia the filament is of such length as to be coiled. This filament is formed of the discs contained within the blood corpuscle. . . "The filament thus formed within the blood corpuscle has a structure which is very remarkable. It is not only flat, but deeply grooved on both surfaces," in an oblique manner. "It is deserving of notice," continues Dr. Barry, "that in the first place, portions of coagulum of blood sometimes consist of filaments having a structure identical with that of the filaments formed within the blood corpuscle; secondly, that in the coagulum I have noticed the ring formed in the blood corpuscle of man, and the coil formed in that of birds and reptiles, unwinding themselves into the straight and often parallel filaments of the coagulum, changes which may be seen also taking place in blood placed under the microscope before coagulation; thirdly, that I have noticed similar coils strewn through the field of view when examining various tissues, the coils here also appearing to be altered blood corpuscles and unwinding; lastly, that filaments having the same structure as the foregoing are to be met with apparently in every which corresponds with the blood disc of the mammiferous vertebrata, viz. the outer or capsular portion of it, the nucleus which alone exists in the blood corpuscles of birds, fishes, and reptiles, being entirely destitute of colouring matter.

The colour of the blood, it has long been believed, is intimately connected with the presence of iron in the blood corpuscles: from the fact, however, that iron exists in the chyle*, and in the colourless blood of certain animals †, it is clear

tissue of the body." These filaments Dr. Barry conceives finally to constitute "fibre," whenever this elementary structure is encountered.

These multiplied and extraordinary observations of Dr. Barry, it is now necessary to observe, remain unconfirmed in all the most essential particulars up to the present time. Shortly after their promulgation, Dr. Griffiths[1], and Mr. Wharton Jones[2], objected to the statement of Dr. Barry, that there exists in the blood corpuscle a primordial fibre, observing that the appearances relied upon were due to decomposition. In connection with the subject of fibre in the blood globules, the analogy referred to by Dr. Willshire[3], between a dark line observed in the starch vesicle, and Dr. Barry's alleged fibre, may be noticed as well as the affirmations of Dr. Carpenter[4], that Dr. Barry had shown him, amongst corpuscles of the blood of the newt, preserved in its own serum, many of a flask-like figure, and which might be compared to a pair of bellows, and the projecting portion of which appeared to Dr. Carpenter to be a filament having a much higher refracting power than the general substance of the corpuscle. Dr. Barry also showed Dr. Carpenter, in blood preserved in corrosive sublimate, a corpuscle which was evidently destitute of the ordinary nucleus, and which contained what appeared to be a filament, presenting transverse oblique markings which resembled those of the fibrillæ of a muscle. The observations of Dr. Barry, and the confirmatory statements of Dr. Carpenter, will at least be possessed of historical interest, if any real and intrinsic importance be denied to them. The views of Dr. Barry are given at length in the Philosophical Transactions for 1840—1843.

* See article "Lymphatic System," by Mr. Lane, Encyclopædia of Anatomy and Physiology, April, 1841.

† "The Blood Corpuscle considered in its different Phases of Developement in the Animal Series, by J. W. Jones, F.R.S. Transactions of the Royal Society, Part II. for 1846.

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[1] Annals of Natural History, February, 1843.

[2] Transactions of the Royal Society, December, 1842.

[3] Annals of Natural History, 1843.

[4] Annals of Natural History, 1842.

that the mere presence of iron is not in itself sufficient to account for the colour of the blood; this depends most probably upon the state of combination of the iron in the blood.

Liebig states, as will be shown immediately, that the iron in the blood exists in the varying conditions of peroxide, protoxide, and carbonate of the protoxide of iron.

USES OF THE RED CORPUSCLES.

In connexion with Respiration. — Observation has taught us the fact that the colour of the blood changes considerably according as it is exposed to the influence of oxygen and carbonic acid gases, it becoming bright red under the influence of the former, and dark red, almost black, under that of the latter gas.

Now the microscope has revealed to us the additional fact that the colouring matter of the blood resides within the red corpuscles; and hence we are led to infer that the changes of colour alluded to are accompanied by alterations in the condition of the colouring matter contained in those corpuscles.

Further, the alterations of colour which have been mentioned take place not only in blood withdrawn from the system, but also in that which still circulates in the living body, the vital fluid being exposed in the lungs to the influence of the oxygen contained in the atmosphere, and to carbonic acid in the capillary system of vessels.

But it is not merely a change of colour which the blood undergoes, or rather the coloured blood corpuscles undergo, on exposure to either of the gases particularised, but they also experience at the same time, as might easily be inferred, a positive change of condition, a portion of one or other of the gases to which the blood corpuscles are exposed being imbibed by them.

That it is really the red corpuscles which absorb the oxygen, or the carbonic acid, as the case may be, admits of demonstration, and is proved by the fact that these gases lose but little volume when placed in contact with the *liquor sanguinis*, or serum of the blood.

It is clear, then, that the coloured corpuscles are the seat in which these changes occur. Again, from the fact that the blood becomes bright red or arterial on exposure to oxygen, as in the lungs, and dark red or venous on being submitted to the action of carbonic acid, as in the capillaries, it has been inferred that they are first carriers of oxygen from the lungs to all parts of the system, and second, vehicles for the conveyance of carbon back again to the lungs.

This inference is correct as far as it goes, but it fails to explain why the imbibition of oxygen or carbonic acid gases should be accompanied by changes in the colour of the blood; and it also fails to show why those gases themselves should be imbibed.

From the constant presence of iron in the coloured blood corpuscles, it has been inferred that this is the base with which the oxygen and the carbonic acid gases combine, but the exact nature of the combinations thus formed it was reserved for the illustrious Liebig to make known.

Liebig declares, that in arterial blood the iron is in the state of a peroxide, and in venous blood in the condition of a carbonate of the protoxide.

To this conclusion Liebig has arrived by observing the manner in which the above-mentioned compounds of iron comport themselves when not in connexion with the blood, but when exposed to the same influences as the blood itself is subjected to.

Thus he says, "The compounds of the protoxide of iron possess the property of depriving other oxidised compounds of oxygen, while the compounds of peroxide of iron under other circumstances give up oxygen with the greatest facility."

Again, "Hydrated peroxide of iron, in contact with organic matters destitute of sulphur, is converted into carbonate of the protoxide."

Lastly, "Carbonate of protoxide of iron in contact with water and oxygen is decomposed, all the carbonic acid is given off, and by absorption of oxygen it passes into the hydrated peroxide, and which may again be converted into a compound of the protoxide."

Now, the above described changes, which the compounds of iron when exposed to the same influences as the blood corpuscles are themselves submitted to, precisely correspond with those alterations which it is known and ascertained that the blood corpuscles do themselves experience, and therefore there is every probability in favour of the strict accuracy of Liebig's explanation of the chemical changes which the blood corpuscles pass through during respiration and circulation.

Thus it has been long known, that in the lungs the coloured blood corpuscles give off carbonic acid and imbibe oxygen: it has also been ascertained that during their circulation they lose a portion of their oxygen and acquire carbon.

Venous blood, then, exposed to the air gives out carbonic acid and absorbs oxygen, but arterial blood submitted to the same influence gives out oxygen and acquires carbonic acid, the seat of these changes being the red corpuscles.

It will be seen on reflection, that, according to the views just propounded, the surplus amount of oxygen which exists in the peroxide becomes disengaged in the reduction of that oxide to the state of protoxide: during circulation in the capillaries, this surplus is chiefly expended in the elaboration of the different secretions which are continually being formed in the various organs of the body.

Such is the *corpuscular theory of respiration.* Hereafter we shall have to speak of a *corpuscular theory of nutrition growth and secretion.*

In connexion with Secretion.—It is very probable that the use of the red corpuscles is not limited to the mere office of carrying oxygen from the lungs to be distributed to all parts of the system, and of carbon back again to the lungs to be eliminated, but that they have an ulterior and additional function to discharge. Thus some observers suppose that they exert some influence over the constitution of the blood itself, elaborating from the materials continually thrown into it by the thoracic duct a further quantity of fibrin. There is more reason to believe, however, that it is the white corpuscles which are principally concerned in this process of elaboration, seeing that their structure agrees with that which is generally possessed by true secreting cells. I therefore myself would be inclined to attribute to the red corpuscles but little influence over the constitution of the blood.

It may be stated that both Wagner * and Henle are of opinion that the red corpuscles are connected with secretion, and the latter, in his "General Anatomy," calls them "swimming glandular cells."

Effects of Re-agents.

The blood globules are much modified by the application of numerous re-agents, and which, therefore, may be employed with advantage in their investigation.

Serum.—It has already been observed, that, in the serum of the blood, their natural element, the globules preserve unaltered, for a time, their normal form.

Water.—The application of water causes the globules almost immediately to lose their flattened and discoidal character, the depressions on their surface are effaced, and they become spherical. This change in the form of the corpuscles is necessarily accompanied by a diminution of their size. (See Plate I. *fig.* 3.)

Spirits of Wine, Æther, Creosote.—The same results follow the use of a variety of other liquids, as spirits of wine, æther and creosote. These agents however, in addition, render the globules exceedingly diaphanous, so much so indeed as that they are often with difficulty to be discovered. In the globules rendered thus transparent, no traces of granular contents can be detected.

Acetic acid.—This preparation first deprives the globules of their colouring matter, thus rendering them exceedingly transparent, and subsequently dissolves the human blood corpuscle, without residue, but not that of the frog, &c., the nucleus of which remains entire. (See Plate II. *fig.* 5.)

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* Physiology, by Willis, part ii. p. 448.

Ammonia.—This alkali acts in a similar manner.

Nitric Acid, Muriate of Soda.—These re-agents contract the globules, and render their outlines more distinct.

Iodine.—This likewise renders the outlines more distinct, without at the same time deforming and otherwise altering the globules.

Corrosive Sublimate.—In a strong solution of this liquid, the outlines of the globules are more defined, and the globules may be preserved for examination for a considerable length of time.

We shall next pass to the consideration of the white globules, and show in what particulars of form and structure they differ from the red.

WHITE GLOBULES.

The white globules of the blood are by far less numerous than the red; they nevertheless are more abundant than a superficial observer would suppose: this arises from the fact that many of them are concealed from view on the field of the microscope by the red globules, which so greatly outnumber them. The white corpuscles differ from the red in several particulars—in size, in colour, in form, in structure, in their properties, and doubtless also in their uses.*

Size.—In man and the mammalia the white globules are generally larger than the red: like those, also, their dimensions vary very considerably in the blood of the same individual abstracted at any given time, and even to an extent still greater. Their average size, when contained in the serum of the blood, may, however, be estimated at about the $\frac{1}{2570}$ of an inch† (see Plate I. *fig.* 1.): when immersed in water, however, they swell up, and increase very considerably in size, in this liquid sometimes measuring the $\frac{1}{1800}$

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* Spallanzani was the first to notice the existence of two forms of globules in the blood of salamanders; Müller verified their presence in that of the frog, and M. Mandl detected them in man and mammalia.

† Mr. Gulliver gives the $\frac{1}{2900}$ of an inch as the average measurement of the human colourless blood corpuscle.

of an inch. (See Plate I. *fig.* 6.) In the blood of reptiles, especially in that of the frog, a contrary relation between the size of the red and white globules exists; the latter in these, instead of being larger than the red corpuscles, are two or even three times smaller. This fact it is important to bear in mind in considering the question of the transformation of the white globules into red.

Form.—Instead of being of a flattened and disc-like form, as are the red globules, the shape of the white corpuscle, when free, is in all classes of the animal kingdom globular. This particular likewise throws much light upon the disputed point as to whether the white globules become ultimately converted into red corpuscles, and which we shall have to treat of more fully hereafter.

Like the red corpuscles, however, although to a less remarkable extent, the white globules, when subject to pressure, undergo a change of form: this change is frequently well seen when viewing the circulation of the blood in the capillaries, the white corpuscles often becoming compressed between the walls of the vessels and the current of red blood discs, and by which compression they are made to assume elongated and oval forms; like the red corpuscles, also, they immediately regain their normal form, the pressure being removed.

Structure.—In almost every relation which can be named, the white globules would appear to be the antagonists of the red; for, instead of being of a homogeneous texture, they are of a granular structure throughout, each full-sized white globule being constituted of not less than from twenty to thirty distinct granules, the presence of which imparts to it a somewhat broken outline: these granules are often seen, especially after the addition of water, and some other reagents, to be in a state of the greatest activity in the interior of the corpuscles. It is only in the blood globule of mammalia, however, that we find this antagonism to prevail. The blood corpuscle of the frog, and doubtless of other reptiles, as well as birds and fishes, is assuredly a compound structure, the investing or transparent part of each being in no way, as regards structure, distinguishable from the substance of the human blood disc, and the nucleus also being identical in composition, though not in origin, with the white globules of the blood, not merely of mammalia, but likewise of reptiles, birds, and fishes. (See Plate II. *fig.* 5.) The form of the nucleus, in the frog, &c., corresponds with that of the globule; that is, it is elliptical (see Plate II. *fig.* 2.): water, however, affects the nucleus, as first observed by Mandl, in the same way as it acts upon the corpuscle itself, rendering both perfectly spherical. (See Plate II. *figs.* 3. and 4.) If to globules in this condition acetic acid be added, the capsule will be dissolved, leaving intact the nucleus, between which and a white globule I have not been able to detect, although using an instrument of the very best description, the slightest structural difference: a difference does certainly exist, but it is one of size, and not of structure, the nucleus being three or four times smaller than a white globule of ordinary dimensions. (See Plate II. *fig.* 5., and Plate II. *fig.* 1.) This identity of organisation between the white globule and the nucleus of the blood disc of the frog, furnishes the strongest evidence with which I am acquainted of the convertibility of the white globules into red, evidence which, nevertheless, I regard as wholly inadequate to demonstrate the reality of the conversion.

Nucleus.—The white corpuscles, under some circumstances, would appear to be nucleated; thus nuclei are evident in corpuscles which have been immersed in water, or even in serum, for any length of time, although they are not usually seen in those of that fluid immediately after its abstraction from the system. I am inclined to regard their formation as resulting partly from the operation of endosmosis, whereby a portion of the contents of each corpuscle becomes condensed in the centre.

The nucleus occupies sometimes the entire of the interior of the corpuscle, a narrow and colourless border, destitute of granules, alone indicating the extent of the corpuscle; generally, however, it is about the one third of its size, and is more frequently excentric than centric. It is usually darker than the rest of the corpuscle, and would appear to contain a greater number of molecules. (See Plate I. *fig.* 6.) Sometimes it presents to the eye of the observer the appearance of an aperture; this appearance, although very striking, is most probably fallacious.

Mr. Addison regards the nucleus presented by the white corpuscles as primary, an opinion in which I concur.

Properties.—The white corpuscles of the blood differ not less in their properties from the red than they do in form and structure: thus acetic acid, which dissolves the latter, contracts somewhat the former, and renders the contained granules more distinct; in water the red globules become globular and smaller in size, while the white increase considerably in dimensions in the same liquid (see Plate I. *fig.* 6.), and finally burst in it, their molecular contents escaping. In *liquor potassæ* both the red and white corpuscles are destroyed and dissolved; previous to which, however, in the white globules, some interesting changes are seen to take place; immediately on the application of the alkali the molecules contained in their interior are observed to be in active motion, and in a short time the corpuscles burst open, or explode, discharging numerous granules, amounting sometimes to thirty or forty; and which, together with the transparent matter of the corpuscles, finally becomes dissolved.—"Frequently when the liquor potassæ is acting with diminished energy, the corpuscles give a sudden jerk, and in a moment enlarge to double or three times their former size, without losing their circular outline: the molecules and granules within them are more widely separated from each other, but not dispersed; and they are seen held together, or attached to the tunic of the corpuscle, by delicate connecting filaments. This singular and instructive change does not, of course, last long; the alkali, continuing its action, ruptures the tunic of the corpuscle, dispersing and dissolving its contents."—*Addison.*

When examined in the living capillary vessels they are seen to manifest different properties to the red, and also to have a very different distribution in those vessels. Thus the white corpuscles frequently adhere to the inner wall of the capillaries, which the red rarely do; and while the red globules, in circulating, occupy the centre of each vessel, the white corpuscles are placed between this and the walls of the vessel.

A difference may also be observed in the relative speed with which the two kinds of corpuscles circulate, the red flowing onwards with greater rapidity than the white. The forces which determine the circulation in the vessels would appear to act only on the red corpuscles, the motion of the white globules being entirely of a secondary and indirect character, it being communicated to them by the edge of the current in the axis of which the red corpuscles move, in the same way as the stones at the bottom of a stream are rolled over and borne onwards by the superincumbent water.

The cause of the slower motion of the white corpuscles in the capillaries may be thus explained. A greatly retarded motion of the fluid circulating in any vessel or channel is always observed towards the periphral border of the current. This retardation would appear to arise from the resistance which the circulating fluid encounters by coming in contact with the walls of the vessel or sides of the channel through which it flows.

In what way, however, is the difference in the position in the vessels occupied by the red and white corpuscles to be explained? why do the former always circulate in the axis of the vessel while the latter are constantly placed outside this? and what is the inference to be deduced from this difference in their situation?

The red corpuscles, as we know, are flattened discs, constituted of an elastic and yielding material; and the white, on the contrary, are globular bodies of a more dense composition and of but little elasticity: now it is very probable that the peculiar form and properties possessed by the coloured corpuscles of the blood may result in such an adaptation and arrangement of them, the one with the other, that a physical impossibility is presented to their indiscriminate admixture and circulation in the same vessel with the white corpuscles.

But there are other facts which will serve to explain the difference of position: thus the red corpuscles have an attraction for each other, as is manifested on the field of the microscope by the formation of the strings of corpuscles already referred to, where also it is seen that they have no such affinity for the white corpuscles, which usually lie detached and isolated from the red. On the other hand, however, the white, as before stated, have an attraction for the walls of the vessels through which they pass, and which is declared by their frequent adhesion thereto.

The question may be asked, have these attractions any thing to do with electric conditions? All the inquiries which have been undertaken with the view of proving that the blood is possessed of electric properties have hitherto signally failed to demonstrate the existence of any.

Lastly, what inference is to be deduced from the different positions occupied by the two kinds of blood corpuscles, and from the different rates of their circulation in the capillaries?

The rapid passage of the red corpuscles through the capillaries, together with their central situation, would lead the observer to infer that they had but little direct relation with the parts outside those capillaries, that the office discharged by them was one of distribution, whereas the slow progress of the white corpuscles through the capillary vessels, as well as their peripheral position, would lead to the conclusion that a close relation existed between them and the parts adjacent and external to the vessels. Now these deductions are precisely those which other facts and observations tend to confirm and establish, as we have already seen in reference to the red corpuscles, and as we shall immediately proceed to show in relation to the white globules.

While viewing the capillary circulation, it is easy to convince oneself that no contraction of the parietes of the capillaries occurs, and that, therefore, the motion of the blood is independent of any action of those vessels themselves, on their contents.

USES OF THE WHITE CORPUSCLES.

The uses of the white corpuscles have not as yet been fully determined; enough, however, of their nature has been ascertained to show that they are closely connected with the functions of *Nutrition* and *Secretion*. We shall here invert the natural order in which the description of these subjects should be entered upon, and speak first of secretion.

Uses in connexion with Secretion.—It would appear that, for the most part, secretions are formed in cells: the correctness of this statement is, in some degree, proved by the fact that the lower classes of the vegetable kingdom are entirely constituted of cellular tissue.

It is also further supported by the fact, that the essential structure of all glands in the animal frame is that of cells.

It would appear, also, that the cells, entering into the composition of a single organ, have the power of producing more than one kind of secretion. This is witnessed in the petals of many flowers, the cells of which frequently elaborate fluids of several distinct colours.

There is much reason to believe, that the granules, which are so constantly associated with the cells, are the active agents engaged in the production of the secretion, the exact constitution of these granules determining the character of the secreted product.

Now, in the white corpuscles of the blood we have precisely the same granular constitution which is seen to belong to cells which are indisputably engaged in the process of secretion.

From the observation of these and other facts Mr. Addison has been led to entertain the opinion, that the white corpuscles of the blood "are very highly organised cells, from which the special tissues and the secretions are elaborated."* In continuation of this subject, Mr. Addison goes on to remark,—"And it appears that the renovation of these tissues and secretions from the blood does not take place by the cells discharging their contents into the general mass of the circulating current, to be separated therefrom by some peculiar transcendental and purely hypothetical selective process of exudation, through a structureless and transparent tissue, but by being themselves attached to, incorporated with, and performing their special function in the structure."

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* Experimental Researches, Transactions of Prov. Med. and Surg. Association, vol. xii. p. 260.

Thus Mr. Addison conceives that the fibrillating *liquor sanguinis* is formed and elaborated in the white corpuscles of the blood, and that it never exists in that fluid in a free state, and that its presence in the crassamentum, and especially in that part of it which constitutes the buffy coat, arises from the rupture and destruction of the white corpuscles and the escape of their contents. This opinion he supports by a series of ingenious experiments, one of which may here be referred to. The tenacious property belonging to mucus is well known, in which respect, as well as in the smaller number of globules, similar to the white corpuscles of the blood, contained in it, it differs mainly from pus. Now, by the addition of a drop of *liquor potassæ* to a little pus, which was previously white and opaque, and in which the presence of a considerable number of white corpuscles was ascertained by means of the microscope, its appearance underwent a complete change, the pus became transparent and tenacious, presenting precisely the characters of mucus. The fluid being again examined microscopically, it was found that most of the globules were ruptured and dissolved, and that the liquid portion of it fibrillated in the same way as that of mucus, and that of the *liquor sanguinis;* from this and other analogous experiments Mr. Addison formed the conclusion, that the fibrillating *liquor sanguinis* was derived from the white corpuscles, and that it does not exist in the blood in a free condition.

According to Mr. Addison, the secretions, "milk, mucus, and bile, are the visible fluid results of the final dissolution of the cells." Hence, therefore, a secretion is the result of the last stage of the process of nutrition. And, again, "If, therefore, the colourless blood corpuscles be termed "parent cells," they must be considered as pregnant with the embryo materials of the tissues and secretions, and not with "young blood cells."

It is scarcely necessary to observe that these highly ingenious views of Mr. Addison are by no means established. That the cells of glands and their contained granules are intimately connected with secretion there are many facts to prove; but that the white corpuscles of the blood are, in the animal economy, the special organs of secretion, and also that the secretions said to be elaborated by them, escape from them, not by transudation through their membranes, but are set free by the entire and final dissolution of the corpuscles, are views which cannot be safely adopted until much additional evidence is adduced in support of them.

The opinion entertained by Dr. Barry, that the colourless corpuscles are "parent cells," seems to me to be purely hypothetical.

Let us now bestow a few reflections upon *Nutrition.*

Uses in connexion with Nutrition.—That the white corpuscles are concerned in the process of nutrition, there is more evidence to show than there is in favour of their connexion with that of secretion. The question to be solved, however, is, in what way do these corpuscles administer to nutrition? do they contribute to nutrition and growth, by their direct apposition to and incorporation with the different tissues of organs? This is the opinion of Mr. Addison, who says of them, that they are the "foundations of the tissues and the special secreting cells, the link between the blood and the more solid structures, the unity from which the pluralities arise."

Dr. Martin Barry also adopts the notion that tissues are formed by the direct apposition of the blood corpuscles. Dr. Barry makes no exact distinction between the red and the colourless globules; but from the fact of his calling the latter "parent cells" filled with "young blood discs," it would appear that he considered that the red corpuscles gave origin to the different structures of the body by their direct union and incorporation with each other. This view is far less tenable than that of Mr. Addison, and neither is supported by a sufficient number of facts to render its accuracy any thing but exceedingly problematical.

That the white corpuscles of the blood are engaged in the process of nutrition is proved by the fact, that they are found in increased quantities in vessels which are actively administering to that function. This accumulation is witnessed also in the capillary vessels of any parts which are subjected to irritation of any sort, and in which, as a consequence of that irritation, there is augmented action.

The gradual collection of the white corpuscles of the blood in the capillary vascular network, may be seen to the greatest possible advantage in the tongue of the frog, as also in the web of the foot of that conveniently formed creature, as the result of continued exposure of the parts to the action of air.*

But it is not alone the aggregation of the colourless corpuscles that may be seen *in* the minute vessels; their escape *from* those vessels may likewise be determined by a prolonged examination of them. If, after the continuance of this congested condition of the vessels for twenty-four or thirty-six hours, they are again examined, it will be obvious that certain of the corpuscles have become entangled in the fibres which form the walls of the vessels, and that certain others have altogether passed the boundaries of the vessels, and now lie external to them.

Again, it is asserted, that the epithelial cells are derived from the white corpuscles of the blood. If this be correct, it would appear that the escape of these corpuscles is a perfectly normal and natural occurrence.

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* Mr. Addison states that, in order to insure a satisfactory exhibition of this important and curious phenomenon, the parts should be irritated in some manner, as by immersion for a minute or two in warm water at a temperature of 95° Fahrenheit, or by permitting a few crystals of common salt to dissolve upon it. These methods I have tried, and have found that they have usually resulted in the entire cessation of the circulation in the capillaries, and this has been also the case even when a weak solution of salt in water has been applied.

Thus far, then, the endeavour to prove the transformation of the colourless corpuscles of the blood into tissue cells, would appear to be successful; but it is here the chain of evidence breaks; and beyond the fact which is by no means established, of their constituting epithelial cells, we have no further proof to adduce of their structural incorporation with the living tissues. Of this occurrence it would, of course, be difficult to procure satisfactory demonstration, on account of the opacity of the parts on which our examination would have to be conducted. It may be remarked, however, that, if founded in fact, we should expect to find a greater correspondence in the size and form, &c., of the elementary tissues, with that of the corpuscles from which, according to some observers, those tissues are derived.*

The *corpuscular theory of nutrition*, then, proposed by Mr. Addison, in the present state of our knowledge can only be sustained by having recourse to a certain amount of theoretical reasoning or to particular assumptions.

The fact, however, still remains to us, that the white corpuscles are concerned in nutrition, although the precise manner in which they are so is still open to investigation, and this fact is strengthened and confirmed by the phenomena of disease. Thus, there is much evidence to show that, wherever nutrition is impeded, the colourless corpuscles accumulate in increased quantities in the vessels; and it is by this accumulation, also, that we are enabled to account for the critical abscesses and discharges which characterise some affections, and to recognise the importance which ought to be attached to their occurrence.

That the colourless corpuscles are really present in increased numbers in the blood, in disease, is attested by the evidence of numerous observers: thus, Gulliver†, Davy‡, and

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* The cells of the liver and spleen resemble closely in appearance the white corpuscles of the blood: between them, however, well-marked differences exist, so that it is by no means to be inferred that the former are derived directly from the latter.

† Appendix to Gerber's General Anatomy, p. 20.

‡ Researches, Phys. and Anat. vol. ii. p. 212.

Ancell*, have observed them in unusual quantities in inflammatory affections, and especially in such as are attended with suppuration. Mr. Siddall and Mr. Gulliver have repeatedly observed them in vast numbers in the horse, especially when this animal has been suffering from influenza. Donné has likewise recognised their presence in increased quantities in disease; and Mr. Addison finds them to abound in the hard and red bases of boils and pimples, and in the skin in scarlatina and in most cutaneous affections.

Several processes have been pointed out by which the white globules may be separated from the red, and thus be brought in a manner more satisfactory under view. 1st. Acetic acid dissolves the red corpuscles, leaving the white almost unchanged. 2nd. A drop of water floated gently across a piece of glass, on which a small quantity of blood has been placed, will remove the red corpuscles, the white remaining adherent to the surface of the glass. This ingenious method was, I believe, first indicated by Mandl. 3rd. The third process depends for its success upon the defibrination of the blood by whipping, and which has already been alluded to. If blood thus defibrinated be set aside for a time, the red globules will subside to the bottom of the containing vessel, forming one stratum, and the serum will float upon the top, constituting a second layer; but between these two layers a third exists; this is very thin, and is formed by the white globules, which may be reached after the removal of the serum by means of a siphon.† Donné points out this method in his excellent "Cours de Microscopie." 4th. A fourth means of procuring the white globules is described by Mr. Addison. If a portion of fluid fibrin be removed from beneath the pellicle which is first formed over the clot, it will be found to contain numerous white globules.

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* Lectures in the Lancet, 1839-40, vol. ii. p. 777.

† The position occupied in this case by the white corpuscles shows that they are of lighter specific gravity than the red, a reference to which fact will also account for their presence, in such quantities, in the buffy coat of the blood, and will likewise explain the reason why they first come into focus when mixed with the red globules in a drop of water.

The observer, having satisfied himself of the accuracy of the various facts brought under his notice, in the next place will be prepared to enter into the important questions as to the origin and destination of the globules of the blood. We will consider first the origin of the white globules.

ORIGIN OF THE GLOBULES OF THE BLOOD.

The origin and end of the blood globules! Whence do they come, and whither do they go? These are questions of the highest importance; and it could be wished that the replies to them were of a more satisfactory and definite nature than those which we are about to make will, it is feared, be considered.

Origin of the White Globules.—Various opinions have been entertained in reference to the nature and origin of the white corpuscles of the blood, the principal of which we will now proceed to notice.

One of the earliest notions formed respecting the white corpuscles was that of Hewson, who believed that they were to be considered as the nuclei of the red blood corpuscles, and hence he denominated them "*central particles:*" to this conclusion Hewson was doubtless led by observing the great and remarkable resemblance which exists between the nuclei of the blood globules of certain animals and the white corpuscles themselves.

Two facts, however, are known, which satisfactorily prove that the denomination of central particles is not applicable to the white corpuscles, and that they do not form the nuclei of the red blood discs: the first of these is, that no nuclei exist in the true blood globules of the entire class of mammalia in which white corpuscles are abundantly encountered, and the second is the great difference in size observed between the nuclei and the white corpuscles in those animals in which the two organisms exist together in the blood.

An opinion somewhat similar to the above has been held by some observers, viz. that the white corpuscles are to be regarded as the "*escaped nuclei*" of the red blood corpuscles. The facts adduced to disprove the former notion respecting them are likewise sufficient to show the fallacy of that just referred to.

By Dr. Martin Barry the white corpuscles are considered to be the last stage of the development of the red blood disc, and he has assigned to them the designation of "*parent cells,*" under the impression that the granules, of which many are contained in each corpuscle, become developed into new blood discs; this idea of Dr. Barry is purely hypothetical, and its accuracy is but little probable.

Mr. Addison also believes that the white corpuscles represent an advanced condition of the growth of the red blood disc, but he differs from Dr. Barry, however, in not considering them to be parent cells, filled with young embryos, designating the white corpuscles "*tissue cells,*" under the belief that they become incorporated with, and constitute an integral portion of the solid structures of our framework. The value of this theory has already been discussed.

Mandl denominates the white corpuscles "*fibrinous globules,*" and he conceives that the nuclei, which he states belong to all red corpuscles of the blood, as well as the white globules, are not primary formations, but secondary, — that these structures do not exist in the blood while circulating within the body, but that they are formed after its abstraction therefrom; and M. Mandl further states, that the steps of the formation of the white globules may be witnessed on the port object of the microscope. That this view is incorrect not the shadow of doubt can be entertained. The regular form and size of the white globules, their presence in the blood the moment after their abstraction from the system, but especially the fact that they may be seen in vast quantities in that fluid while still circulating in the capillaries, all negative the idea of the formation of the white globules out of the system, in obedience to a mere physical law.

Mr. Wharton Jones, in a recent communication made to the Royal Society, has bestowed upon the white corpuscles the appellation of "*granule cells,*" and that gentleman considers them to represent an early stage in the development of the red blood globule. The peculiar views entertained by

Mr. Jones will, however, be referred to more fully under the head of the origin of the red blood disc.

The white corpuscles are also synonymous with the "*exudation corpuscles*" of many writers, and especially of Gerber, who has under this denomination assigned to them a false value; the presence of the white corpuscles in the plastic fluid of exudations being rather accidental than essential.

We come now to refer to the opinion entertained respecting the white corpuscles by Müller, who denominated them "*lymph corpuscles*," conceiving them to be identical with the granular corpuscles encountered in the lymphatic fluid. Of all the opinions and theories of the nature of the white corpuscles alluded to, that of Müller is probably the only correct one: Müller, however, was not acquainted with their existence in the blood of mammalia, but merely in that of frogs and other analogous animals.

The opinion that the white corpuscles are red blood globules in process of formation is one which is maintained by many observers, and nevertheless I regard it as erroneous. In the truth of this view Wagner, Baly, Gulliver, Professor H. Nasse, and above all Donné, are believers. From the excellent work of the latter writer I introduce the following remarks in relation to this point:—

"About two hours after injection (with milk), rabbits, dogs, and birds have been opened. I have collected the blood in the different organs, in the lungs, the liver, and the spleen; everywhere I have found the blood in the state in which I have described it above, containing a certain number of white globules in all stages of formation, and of red globules more or less perfect: invariably the spleen has presented to me special circumstances so established and so constant that it behoves me to mention them, and especially since they may throw light, at length, upon the true functions of this organ, so long and so vainly sought. I do not dare flatter myself with having completely resolved this problem, and it is but with reserve that I express myself in this particular.

"The blood contained in the large vessels of the spleen offers nothing very remarkable; but, in expressing that which is enclosed and, as it were, combined with the tissue of this organ, one finds in it a composition well worthy of fixing the attention. In a word, this blood is so rich in white globules, that their number approaches nearly to that of the perfect blood globules; but, further, the white globules which are there, present in as evident a manner all the degrees of formation and development, and the examination of this blood does not appear to me to leave any doubt upon the transition which I have pointed out above of white globules to red corpuscles, and upon the successive phases through which the white globules pass to arrive at the state of perfect blood globules. This phenomenon is, above all, striking after injections of milk, and during the work which is accomplished in the space of four and twenty hours, of the transformation of the immense quantity of milk globules into blood globules. One cannot believe that this is not really the point—the laboratory, if one may so speak—in which this transmutation is effected, and that the spleen is not the true organ of this important function. But I know how like facts, and how the theory which results from them, have need to be confirmed by the researches of other observers, to be definitively adopted with confidence."*

In answer to these observations of M. Donné I would remark, first, that I have never seen the different stages of formation of the white corpuscles, and of transformation of these into red, described by M. Donné, and, second, that I believe that he has totally misinterpreted the appearances presented by blood pressed out of the spleen. The cells or corpuscles of which that organ is itself constituted so closely resemble the white globules of the blood, that I feel assured that M. Donné has failed to discriminate between the two, and that many of his progressive stages of development are to be referred to the splenic cells or corpuscles, numbers of which are always contained in every drop of blood procured from the spleen.

Having now noticed the various opinions held by different observers in reference to the nature of the white corpuscles, we will next pass to the consideration of their origin or mode of formation. The idea that the white corpuscles are elaborated by the lymphatic glands has already been referred to; and, from the absence of these glands in the lower oviparous vertebrata, it is evident that they cannot be regarded as essential to their formation.

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* Cours de Microscopie, pp. 99, 100.

It has been stated that, in addition to the white and red globules, numerous smaller particles, termed molecules, exist in the blood. The white globules, in all probability, derive their origin from these molecules, a number of them going to constitute a single white globule. This aggregation of the molecules into masses, or globules, would appear to result from the operation of a general law of the economy, under the influence of which the globules unite with each other, and become invested with a coating, or membrane, probably of an albuminous nature.

Donné believes also that he has traced, by direct observation and experiment, the transformation of the minute oily and fatty particles, found in the milk, into white globules. He injected numerous animals, birds, reptiles, and mammalia, with various proportions of milk, and, strange to say, the creatures thus experimented upon experienced no injurious effect beyond a momentary shock, with, however, the single exception of the horse, to which the experiment proved fatal in seven different cases. If, almost immediately after the injection of the milk, a drop of blood be withdrawn from the system at a distance from the point where the milk was introduced, a number of the globules of the milk may be detected quite unaltered, and which may be recognised by their general appearance, their smaller size, and, lastly, by the action of acetic acid, which dissolves the red globules, renders apparent the granular texture of the white, but leaves untouched the molecules of the milk. If the blood be again examined at about the expiration of two hours, the smallest milk globules will be seen to have united themselves with each other by threes and fours, and to have become enveloped, by circulating in the blood, in an albuminous layer, which forms around them a vesicle, analogous to that which surrounds the white globules. The largest remain single, but are equally enveloped in a like covering. These soon break up into granules, in which state the milk globules bear a close resemblance to the white globules of the blood, from which, finally, they are not to be distinguished. "The blood," Donné remarks, "then shows itself very rich in white globules; but, little by little, these undergo modifications more and more profound; their internal molecules become effaced, and dissolved in the interior of the vesicle, the globule is depressed, and soon it presents a faint yellow colouration: they yet resist better the action of water and acetic acid than the fully formed blood globules, and it is by this that they are still to be distinguished. At length, after twenty-four hours, or, at latest, after forty-eight, matters have returned to their normal state; no more milk globules are to be found in the blood, the proportion between the white globules and the blood globules, between the imperfect and the perfect globules, has returned to what it is ordinarily; in a word, the direct transformation of the milk globules into blood globules is completed."

In the opinion that the milk globules are convertible into the white globules of the blood Donné is probably correct, although it must be an inquiry of much delicacy and nicety to determine this point by direct observation. The evidence, however, in favour of his latter position, viz. that the white globules become ultimately converted into red corpuscles, is much more defective, and the facts upon which he relies to sustain this view are open to question, as we have already seen.

The view, then, of the transformation of white corpuscles into red, I consider to be erroneous, and that the white corpuscles, as they differ from the red, in form, structure, and chemical composition, so they also differ in origin; and that the two forms of corpuscles are in every respect distinct, as well in function as in origin.

From the fact of the white corpuscles of the blood being encountered in considerable quantities in the lymph and chyle, which is in truth blood in its primitive form, it is in those fluids, doubtless, that they take their origin, and it is in them that they are best studied.

Origin of the Red Globules.—It has already been shown that Donné and others consider that the red globules are formed out of the white, which they view as true blood globules which have not reached the last degree of elaboration. Donné sustains this opinion by reference to the following particulars:—First, that amongst the red globules contained in a single drop of blood, all are not affected to the same extent by the use of the same re-agent; that some resist its influence for a much longer period than others; Secondly, he states, that he has observed, in some true blood globules traces of a slight punctuation, similar to that which is seen in the white corpuscles; and, Thirdly, in certain white globules he has noticed the compressed form common to the red corpuscles. From the observation of these facts he draws the conclusion, that the white globules are transformed into red blood discs. The first particular alluded to, viz. that the same re-agent does not affect equally all the red globules of the same blood, is doubtless to some extent correct, and may be explained by supposing that the red corpuscles are not all of the same age, and therefore are of different degrees of consistence. The remarks as to the granular texture of true blood corpuscles, and the compressed form of certain white globules, it has never happened to me to be able to verify in a single instance; and, for my own part, therefore, I am inclined to allow to them but very little weight in determining the question of the origin of the red corpuscles of the blood. To the views of M. Donné on this point a high degree of plausibility and ingenuity must certainly be accorded; but, in considering this question, not merely the doubtful and even debateable nature of the evidence adduced by M. Donné must be taken into consideration, but also the following fact,—viz., that no definite relation exists in the animal kingdom between the size of the red and white globules compared together. In man, and most mammalia, the white globules are larger than the red (see Plate I. *fig.* 1.); in most reptiles, and particularly in the blood of the frog, they are very much smaller (see Plate II. *fig.* 1.): from whence it would result that the process adopted by nature for the conversion of the white globules into red, would, in the two classes of the animal creation cited, be of a character wholly different the one from the other. In the first-mentioned the transmutation would be a work of decrease; in the second, of increase, or superaddition; and this supposition, I conceive, would be tantamount to charging nature with the commission of a gross inconsistency.

There are other observers, again, who believe in the formation of the coloured blood corpuscles out of the colourless ones, in a manner totally different from that described by M. Donné.

Thus Mr. Jones, in a communication recently made to the Royal Society, and entitled "the Blood Corpuscle considered in its different Phases of Development in the Animal Series," states that the blood corpuscle presents throughout the animal kingdom at least two phases of development; in the first of these the corpuscle is granular, and in the second nucleated: when in the former phase it is denominated "*granule blood cell,*" and in the latter "*nucleated blood cell;*" the first condition, or that of granule blood cell, is synonymous with the colourless corpuscle of the blood.

But each of these two phases presents likewise two stages in their growth or formation: thus the granule blood cell may be either *coarsely granular*, or it may be *finely granular;* and the nucleated blood cell may be either *uncoloured* or *coloured.* The first three stages are encountered, according to Mr. Jones, in the whole animal series, but not the fourth stage, the coloured condition of the nucleated blood cell, which is wanting in most of the Invertebrata, and in one of the series of Vertebrate animals, a fish, the *Branchiostoma lubricum* Costa; in all the other divisions of the animal kingdom it is present, as in the Oviparous Vertebrata and the Mammalia.

In the latter class, the Mammalia, a third phase is superadded to the other two, that of a "*free cæliform nucleus:*"

this appellation expresses the usual condition in which the blood disc in the mammalia is encountered, and in which no nucleus can be discovered.

This third phase Mr. Jones considers to be derived from the nucleated blood cell in its second stage; the "free cœliform nucleus" being the escaped nucleus of the nucleated blood cell.

The facts by which this view is supported are, first, a relation in size between the nucleus of the nucleated blood cell and the ordinary blood disc, or "free cœliform nucleus," and second, the occurrence, which is, however, very rare, of nucleated cells from which the nuclei themselves have escaped.

The "nucleated blood cell" Mr. Jones found abundantly in the blood of an embryo ox, an inch and a quarter long; very sparingly in that of the elephant and horse, and not at all in the blood of the human subject: he encountered them, however, freely in the *chyle* of *man*.

Such is a brief statement of the views of Mr. Jones in reference to the blood corpuscle, and of the chief facts by which those views are supported: without taking upon myself to pronounce upon them decidedly, I yet must confess that they carry with them but little conviction to my mind, and that the facts adduced to sustain them are open to considerable discussion.

If the blood corpuscles of animals in general, and of the mammalia in particular, pass through the successive phases and stages described by Mr. Jones, how happens it, I would ask, that in the blood of mammalia, and especially in that of man, while we meet with so abundantly the first stage of the first phase, that of granule blood corpuscle, viz. the coarsely granular stage, and also the last phase indicated by Mr. Jones, that of free cœliform nucleus, we do not frequently encounter the intermediate stages and phase, through which, according to Mr. Jones, the blood corpuscles pass? To this question I do not think it easy to give a satisfactory reply, consistent with the opinions of Mr. Jones. The explanation which I would give of the absence of these transition forms is, that they have no real existence.

According to Mr. Jones the nucleated blood cells of the

Oviparous Vertebrata are of a nature totally distinct from the ordinary blood cells of the Mammalia, which have no nuclei, but that the nuclei of the blood cells of the former are the analogues of the latter; this opinion is scarcely consistent with the difference of structure and chemical composition observed between the two. Opinions very analogous to those of Mr. Jones in reference to the nature of the blood corpuscles of the mammalia, viz. that they are escaped nuclei, appear to have been entertained by Mr. Gulliver from observations made on the horse; this gentleman supposing that the red corpuscle was the escaped nucleus of the white granular corpuscle, while Mr. Jones conceives that the red blood disc is the liberated nucleus of the same body, only in an advanced condition of its development, in the stage of coloured nucleated blood cell.

To the appellations by which Mr. Jones designates two of his phases of the development of the blood corpuscle an exception may fairly be taken. The "granule blood cell" is frequently nucleated, even while it still retains its granular structure, and therefore the term selected by Mr. Jones to indicate a condition of the blood corpuscle distinct from its granular state, viz. that of nucleated blood cell, is inappropriate, and calculated to lead to the inference that the granule blood cell is not a nucleated body.

I reiterate then the opinion, that the white and red globules of the blood are wholly distinct from each other, —distinct in origin, in structure, and in function.

The strongest fact with which I am acquainted (but it is one which is not employed by M. Donné), in favour of the transmutation of white globules into red, is this, — viz. that the nucleus which exists in the blood discs of the frog, and reptiles in general, is of a granular structure, in all respects similar to that of a white globule, with the differences only of size and form, the nucleus being four or five times smaller than a true white globule, and of an oval instead of a circular outline. (See Plate II. *fig.* 5.) One of these differences, as already stated,—viz. that of form, — is effaced by water, which renders the nucleus circular (see Plate II. *fig.* 4.), in which state the only distinction between it and a white corpuscle which can be detected is the single one of size. (See Plate II. *fig.*1.) This difference, however, is so great, and coupled with the fact that no white globules have ever been detected in the frog, putting on the characters of a true red blood corpuscle, that the opinion that the white globules are transformed into red blood discs must again be abandoned. The existence of a granular nucleus in the blood discs of reptiles, &c. revives again the old notion, that the white globules are the escaped nuclei; that they are not so is proved by the fact that no such nuclei exist in the true blood globules of man and the mammalia, in the blood of which white corpuscles abound.* The blood discs, it has been observed, first make their appearance in the chyle: any inquiries, therefore, instituted with the view of determining their origin and development in man, would be more likely to prove successful if directed to the rigorous examination of that fluid.†

In the last place, it remains to treat of the end or final destination of the red globules of the blood.

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* The following interesting remarks of Mr. Gulliver tend to confirm somewhat the views of M. Donné: they are by no means conclusive however:—"White globules about the same size as those in the blood of man, and probably identical with the proper globules of chyle and lymph, are common in the blood of birds, and particularly abundant after a full meal in the vultures and other rapacious families. Some of the red discs, too, instead of the oval form, are often nearly or quite circular in figure. Hence the blood of these birds would appear especially favourable to observe any changes in the white globules; and it seemed highly probable, that these might be transformed into the blood discs in the manner mentioned by Dr. Baly; but although I made many observations with the view of determining this question, nothing but negative results were obtained." (*Appendix to Gerber's General Anatomy*, p. 24.) This observation is satisfactory in one respect, viz. that it shows clearly the connection, which has already been dwelt upon, of the white corpuscles with nutrition.

† For further observations on the development of the red blood disc, see the remarks on the circulation in the embryo of the fowl.

THE END OR FINAL CONDITION OF THE RED GLOBULES.

Every where throughout the solid constituents of the animal organisation cellular tissue abounds; it forms the basis of every texture and organ of the body. It is, therefore, scarcely to be wondered at that the opinion should have been adopted, that the globules which exist in such vast numbers in the blood, were to be regarded as the primary and even parent cells, out of which all the solid structures of our frame took their origin.* This theory, to the mind of the earlier micrographer, must have appeared very rational and seductive; and so great, indeed, is the plausibility with which, even in the present day, it is frequently invested, that it is still able to claim a few adherents.

If we regard with the utmost patience and attention the beautiful spectacle of the capillary circulation in any of the more transparent parts of animals, but especially in the tongue of the frog, we shall in vain look for the escape from their containing vessels of even a single red blood corpuscle, independent of a rupture of those vessels. In a normal state, therefore, the blood globules are never free, but are always enclosed in their own proper receptacles.

A communication, however, between the fluid contents of the blood-vessels and the tissues lying external and adjacent to them, is doubtless established, through the operation of the principle of exosmosis, whereby a slow exudation of the fluid fibrin of the blood is perpetually going forward. Now it is the opinion of most of the German physiologists, and it is the view best supported by facts, that this fluid fibrin is to be regarded as the true *blastema,* out of which all the different elementary tissues and structures of the body proceed, and this not by any power inherent in itself, it being, as respects the final form which it is made to assume, totally inert and indifferent, and which form is impressed upon it by a *vis insita,* or peculiar power and faculty belonging to each organ and structure of the animal fabric.

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* Amongst those who regard the blood corpuscles as cells, may be named Schwann, Valentin, Addison, Remak, and Barry. Schwann describes the blood globule as a "nucleated cell," whilst Valentin considers it to be a nucleus, and that which is usually held to be a nucleus he regards as a nucleolus. Remak states, that he has witnessed the development of the globules as parent cells, not within the blood, but within the cells which line the walls of the blood vessels and lymphatics. The views of Addison are confined chiefly to the white globules, which he conceives to be the fully developed nuclei of the red blood corpuscles, and which he believes to be transformed into epithelial cells, &c. &c. Dr. Barry goes further than this; for he states that every structure which he has examined, arises out of the blood corpuscle, "the crystalline lens itself, and even the spermatozoon and the ovum." The opinions entertained by Gerber seem to be of a nature somewhat similar to the foregoing. It is difficult to understand, however, what his exact sentiments are: they, at all events, go to the extent of supposing that all the solid structures of the body are derived from pre-existing germs, contained in the chyle and blood.

While the fibrin circulates in the blood it retains its fluid form; soon after the cessation of the circulation, and whether within or without the system, it passes from the fluid state to the condition of a solid: now, on the principle of endosmosis, which has to be so often referred to in the explanation of numerous phenomena, in the solidifying power of the fibrin, and in the *vis insita* of the different tissues, we recognise the chief and fundamental causes which regulate nutrition, growth, and secretion.

It would thus appear that the globules of the blood (the red globules are more particularly alluded to) are not to be regarded as either cytoblasts or primary cells, forming by direct apposition the solids of the body, and that therefore they do not express the last degree of elaboration of which the fibrin of the blood is susceptible.

Again, then, we have to ask ourselves the question, what is the end, or final condition, of the red blood globules? Direct observation is wanting to aid us in the solution of this difficult inquiry, which, however, admits of an indirect reply being given: we have seen that no means of egress from the blood-vessels is, under ordinary circumstances, permitted to the red blood globules, and therefore we are driven to the conclusion that, having performed the important function to which we have already alluded, viz. that of carriers of oxygen from the lungs throughout the system, and of carbon from the latter back again to the lungs, they become dissolved, increasing by their dissolution the amount of fluid fibrin circulating in the blood, and which is deemed to be the true *blastema*.

MOLECULES OF THE BLOOD.

In addition to the red and the white globules, there exists, as already mentioned, in the blood a third description of solid constituent, the "molecules:" these are synonymous with the "basin-shaped" granules of Vogel, the "globulins" of Donné, and the "primary discs" of Martin Barry.

The term molecule, or granule, is well suited to designate these particles: for either appellation will serve to convey some idea of their exceeding minuteness, and which is computed rarely to exceed the $\frac{1}{30000}$ of an inch. They occur in great quantities in the blood, either scattered singly throughout it or agglomerated into small and irregularly shaped masses. (See Plate I. *fig.* 6.) The molecules are usually regarded as the elements out of which the blood corpuscles are formed: on this point, however, direct observations are still wanting. It is more probable that the white globules are developed out of them than the red, and this simply by their union or aggregation.*

PECULIAR CONCENTRIC CORPUSCLES.

Besides the red and the white globules and the molecules, which we have described as present in the blood, a fourth species of solid corpuscle has been observed to occur in its fibrinous constituent. These corpuscles have been repeatedly encountered by Mr. Gulliver * in clots of fibrin in man and other mammalia, and are alike to be found in them, whether the clots are formed in the body after death, or in blood abstracted from the system during life.

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* Since the above few lines were written on the "molecules" of the blood, I have repeatedly remarked, that in blood, on its first abstraction from the system, but few molecules were present, while in that which has been withdrawn from the body for some time, they have always abounded. This observation has led me strongly to suspect, that the molecules do not exist in the blood in a free state, but that wherever and whenever they are encountered, save only in the chyle, they are to be considered as derived from the rupture and destruction of the white corpuscles.

These corpuscles, of a very peculiar structure, as will be seen hereafter, Mr. Gulliver has described and figured with extreme accuracy; and he has styled them "organic germs," "primary or nucleated cells," and as capable of further development if placed in circumstances favourable to their growth. Mr. Gulliver, however, would appear to have been quite undecided as to their real nature, and whether they were not to be regarded as identical with the "fibrinous globules" of Mandl.

These peculiar bodies I have myself met with in fibrinous clots which were found in the heart after death; and I have no hesitation in asserting that they differ, in every essential particular, from the fibrinous globules of Mandl, which are identical with the colourless corpuscles of the blood.

The size of these corpuscles is subject to the greatest possible variation; they are frequently smaller than the white globules of the blood, but very generally three or four times larger; their form is also irregular, but inclining, in those which I have examined, to the spherical. They consist of two parts, of nuclei and envelopes: the nucleus is of an irregular outline, and not usually well defined without the aid of re-agents; its bulk is about the one fourth or one fifth of that of the entire corpuscle; the envelope, in all the globules which have fallen under my observation, has been compound, that is, made up of several vesicles concentrically disposed, the one within the other. (See Plate IV. *fig.* 3.)

The appearance presented by these objects bears a close resemblance to the vesicles of certain species of Algæ, of the genus *Microcystis* or *Hæmatococcus,* these being likewise each composed of several concentrically arranged membranes or vesicles.

Now, what is the opinion which ought to be entertained in reference to the nature of these corpuscles? Do they really constitute an integral portion of our organisation? and do they circulate in the living blood? or are they formed in it after death? The opinion of Mr. Gulliver that they are primary, or nucleated cells, has already been referred to: my own impression as to them is, that they do not constitute an integral portion of our frame; and that, whether they exist in the living blood and circulate in it, or are formed in the clot subsequent to decease, they are to be regarded as extraneous formations, probably of an entozoal character.

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* See translation of Gerber, p. 31., and Appendix, p. 16.

It does not appear that the envelopes of all the corpuscles met with by Mr. Gulliver exhibited concentric striæ, although he describes some of them as possessing this striated structure: Mr. Gulliver speaks also of cells three or four times larger than the corpuscles, and capable of containing the latter as nuclei. These I have not myself encountered.

The corpuscles are not usually scattered equally throughout the fibrinous clot, but frequently occur in groups, parts of each clot being altogether free from the corpuscles.

Acid re-agents, especially the sulphurous acid, will be found useful in their examination.*

BLOOD GLOBULES OF REPTILES, FISHES, AND BIRDS.

The red globules of the blood of the reptile, the fish, and the bird, have all certain characters in common with each other, which serve to distinguish them from those of man and the mammalia in general. The chief of these characteristics are their form, their size, the presence of a nucleus, and, lastly, their greater consistence. The compressed form belongs to the red blood globules of all animals; in the three classes of reptiles, fishes, and birds, however, although the globules possess this flattened figure, instead of being circular, as in man and the mammalia, they are in outline elliptical;

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* Since writing the above description, I have met with these concentric corpuscles in connexion with the thymus gland which had been allowed to remain in water for a few hours.

and, in place of having a central depression, this part of each globule is slightly protuberant. This prominence is due to the presence of a nucleus, which in the mammalia we have seen to be absent.

The size of the red globules is as distinctive as their form, it usually exceeding, in reptiles, three or four times that of the majority of the blood corpuscles of mammalia. The blood disc of the frog equals in length the $\frac{1}{1125}$ of an inch, while its transverse measurement is not less than the $\frac{1}{1635}$ of an inch; now the corpuscle of the elephant, the largest known amongst mammalia, reaches only the $\frac{1}{2745}$ of an inch in diameter.*

It has already been remarked that most of the animals of the order *Camelidæ* are possessed of blood globules of an elliptical form, constituting in this respect an exception in the class to which they belong. These oval corpuscles are, however, so small that they could not be readily confounded with the elliptical globules of the frog, &c.: they therefore agree in size, as well as in the absence of a nucleus, with the blood corpuscles of other mammalia, although not in form. While every possible care has failed in satisfactorily demonstrating the presence of a nucleus in the blood of mammalia, not the slightest difficulty is experienced in detecting it in that of the frog and most of the animals belonging to the classes just mentioned, and therefore its presence is generally recognised; although one excellent observer, M. Mandl, is of opinion that its formation takes place subsequently to the removal of the blood from the system: this idea is doubtless erroneous, as we have seen to be the case with respect to the white corpuscles of the blood, regarding which M. Mandl entertained a similar notion. In blood corpuscles immersed in their own serum, and examined immediately after their abstraction, the nucleus may be seen with a sufficient degree of clearness to enable the observer to pronounce with confidence upon its presence. After the lapse of a few minutes it becomes much more apparent, so that its composition is easily to be discerned: this arises, most probably, from the discharge of a portion of the colouring matter of each globule. The form of the nucleus is seen to correspond with that of the blood corpuscle itself, and to be oval, presenting a granular structure precisely resembling that of the white globules of the blood, from one of which it is only to be distinguished by its much smaller size and oval form. (See Plate II. *fig.* 2.)

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* The largest blood corpuscles hitherto discovered in the animal kingdom are those of the Siren and Proteus. In the Siren, according to Mr. Gulliver, the long diameter of the blood discs is the 435th, and the short the 800th part of an inch, while in the Proteus they are stated at about the 350th part of an inch in length.

Owing to the firmer texture and greater size of the blood globules of the frog, their structure can be well studied, and the effects of re-agents more easily determined.

In water, the red corpuscles lose their colour, and become circular, and indeed globular, a change of form which the nucleus is likewise seen to undergo. (See Plate II. *figs.* 3 & 4.) These alterations ensue almost immediately on the application of the water: its continued action produces an effect still more remarkable; the nucleus, which at first occupied a central position in the globule, is soon seen to become excentric, and finally, rupturing the pseudo-membrane of the corpuscle, escapes into the surrounding medium; the nucleus and the outer portion of each globule are then observed as two distinct structures, lying side by side (see Plate II. *fig.* 4.); the latter is at length absorbed, and then nought remains but the nucleus, which is, as already remarked, under the influence of water rendered of a globular form, and which is in no way distinguishable from a white corpuscle of the blood, save in the single particular of size, the nucleus being several times smaller than the globule.

Acetic acid dissolves, if strong almost immediately, the outer tunic, without occasioning the prior extrusion of the nucleus, the form of which is not materially affected, the contained granules merely becoming more clearly defined. (See Plate II. *fig.* 5.)

The white globules in the blood of the frog are very numerous; they bear no similitude of form or size to the elliptical red blood corpuscles, being usually perfectly spherical, and scarcely more than a third of the dimensions of the oval corpuscles. Thus, between the white globules in man and the mammalia and those of reptiles, an opposite relation of size in reference to the red blood discs exists; for while, in the former, the white corpuscles are larger than the red globules, in the latter they are generally much smaller. (See Plate I. *fig.* 1., Plate II. *fig.* 1.)

The plastic property possessed by the blood globules of all animals belongs especially to that of the frog. The globules, if trailed or drawn along the surface of a piece of glass, may be elongated to thrice their original length, and made to assume such forms as are altogether inconsistent with the existence of a thin and distinct investing membrane.* (See Plate II. *fig.* 6.)

CAPILLARY CIRCULATION.

We have now considered the blood, both physiologically and anatomically, out of the system, at rest and dead. We have, in the next place, to treat of it within the body, living and circulating.

The beautiful phenomenon of the capillary circulation may be witnessed in the more transparent parts of several animals; as, for example, in the extremities of young spiders, fins of fishes, in the gills of the tadpole and the newt, in the tail of the water newt, in the web of the frog's foot, and in the mesentery of the smaller mammalia. But it is seen to the greatest possible advantage in the tongue of the frog; an organ peculiarly adapted for the representation of the circulation of the blood, from its extraordinary elasticity and transparence. For a knowledge of this fact science is indebted to a neighbour and friend of mine, Dr. A. Waller, and by whom it was communicated some years ago to M. Donné. For the exhibition of the circulation in the tongue of the frog, in a satisfactory manner, it is necessary that the animal should be secured in the following way:—A bandage having been passed several times around the body of the frog, so as to secure effectually the anterior extremities, it is next to be fastened to a piece of cork by additional turns of the bandage: this piece of cork should be very thin, six or seven inches in length, by about ten in width, and perforated at one extremity by a square aperture, the diameter of which should not be less than two thirds of an inch. To the margin of this aperture, the mouth of the frog, in binding it to the piece of cork, should be brought. The frog having been thus effectually secured, the soft and pulp-like tongue should be drawn out of the mouth by means of a pair of forceps, and being spread over the surface of the aperture, should be retained in position by from four to six pins, the elasticity of the tissue of the tongue allowing of its extension into a thin and transparent membrane with but little risk of a rupture of the organ; lastly, the piece of cork should be fastened to the stage of the microscope, in such a position that the tongue rests over the opening in the stage. These preliminary arrangements being effected, and a low power of the microscope being brought to bear upon it, a spectacle of the highest interest and beauty is revealed to the sight of the beholder. We have displayed before us, in action, almost every tissue of the animal organisation, in its simplest and clearest form and disposition—arteries, with their accompanying veins and nerves; muscular tissue; the blood, with its red and white globules; epithelial cells; glands of the smallest possible complication of structure: and these several parts are not merely visible, but their form, disposition, construction, and normal mode of action, are all distinctly apparent; the blood ever flowing, the muscles contracting, and the glands secreting.

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* The extraordinary elongation of which the blood globules of the frog are susceptible, may be seen to very great advantage by adopting the following little expedient: — A drop of blood being placed upon the object glass previous to its coagulation, and allowed to remain there for a few seconds, until symptoms of consolidation have manifested themselves, it is then to be extended gently with two pins in opposite directions, if now the microscope be brought to bear upon it, elongated corpuscles will be seen in it in vast quantities. In the production of this change it is the fibrin which is mainly concerned; for it is through it that the extension is communicated to the corpuscles.

The circulation in the tongue of the frog is best seen, in the first instance, by means of low powers, a larger surface of the organ being thus brought under view, and a more exact idea obtained of the relative size and disposition of its numerous constituents. The arteries may be distinguished from the veins by their fewer number, smaller calibre, and by the fact that, while the veins increase in diameter, in the direction of the course which the blood contained in them pursues, the arteries decrease in the course which the current follows in them. The arteries, from their origin, diminish in size and multiply in number, by the constant giving off of secondary branches; the veins, on the contrary, become enlarged during their progress, and lessen in number, by the continual addition of subsidiary veins. These differences, as well as the circumstance that the velocity of the blood in the arteries is greater than in the veins, are abundantly sufficient to distinguish the two orders of vessels from each other. If, now, a somewhat higher power be applied to the objects, we shall be able to dive still further into the mysteries of organisation; we shall not merely perceive the general motion of the blood, but also that nearly the entire mass of that fluid consists of red globules. We shall be able to recognise clearly their form, and to see the different modifications of shape which they undergo in passing by each other, and in escaping any impediment which presents itself to impede their progress. We shall perceive, likewise, that, in the smaller capillaries, the globules circulate in single series, and mingled with them will be noticed occasionally a colourless globule, which, in the blood of the frog, is not more than half the size of the elliptical corpuscle. (See Pl. V. *fig.* 2.) Furthermore, it will be remarked that the circulation does not flow on in an uninterrupted stream of equal velocity, but that certain arrests of its motion occur. These are but momentary, and after each the current again quickly flows on with the same speed as before: with each action of the heart, also, a slight impulsion of the blood in the capillaries may be clearly seen.

This instructive sight of the capillary circulation may be viewed thus for hours, during the whole of which time the blood will be seen flowing on with undiminished force. In certain vessels, however, after a very long exposure of the tongue to the action of the air, whereby its moisture is continually abstracted, and which acts, doubtless, as a source of irritation, a number of the colourless globules will be seen to have collected in the capillaries; these adhere principally to the sides of the vessels and to each other, thus leaving the channel still free for the passage of the red globules, which in their course sometimes rush against the white globules with such violence as to detach one or more of them from time to time from its adhesion to the walls of the vessel, and which, rolling over once or twice, joins the general current of the vessel, and is quickly carried out of view. It would appear that any irritation affecting the capillary vessels, even when applied to them outwardly, as, for example, weak chemical solutions, gives rise to the phenomenon in question. It is to be observed, however, that at all times considerable numbers of white corpuscles circulate in the larger capillaries: these do not occur mixed up with the red blood corpuscles; but, as already remarked, are situated externally between them and the inner wall of the capillaries. (See Plate V. *fig.* 1.)

In the plastic power with which the red corpuscles are endowed, we recognise a beautiful and important organic adaptation of matter to the fulfilment of a special purpose. Were it not for this plastic property, and were the red corpuscles of the blood, on the contrary, of a solid and unyielding texture, it would follow, as an inevitable consequence of the solidity of the globules, combined with their vast number, that frequent interruption and stoppage of the circulation in the capillaries would ensue, and which would, of course, result in the complete derangement of the functions of the entire economy.

I come now to record an observation which, so far as I am informed, is without parallel. On one occasion, in examining the tongue of a frog a portion of it broke away from the remainder; this I placed between two plates of glass, and submitted to examination, when, extraordinary to say, it was perceived that the circulation was still vigorously maintained in the majority of the vessels. Anxious to know how long this circulation would be continued, but fully expecting to see it cease every moment, myself and a friend, John Coppin, Esq., of Lincoln's Inn, watched it for upwards of an hour, at the end of which time the blood still flowed onwards in many of the vessels, with scarcely abated vigour, though in others, often the larger ones, the motion had altogether ceased. The mutilated portion of the tongue was then placed in water, in which it remained during the whole of the night; the next morning it was again examined, when it was found that a tolerably active circulation still existed in several of the smaller vessels. After this observation the further examination of the fragment was abandoned. The almost immediate cessation of the circulation, which occurred in some of the larger vessels, admits of explanation in the following way:—In some vessels the blood globules were seen escaping from their open extremities; this effusion of the globules frequently continued for two or three minutes, until the entire contents of such vessels became poured out, when of course the circulation within them ceased, the circulating fluid being expended; in other capillaries the current was seen to stop long before their contents had been exhausted, in which case it was usually to be remarked that some of the blood corpuscles contained in the vessels had collected around their orifices, thus producing an impediment to the further maintenance of the current.

The foregoing observation is one of much interest and importance; for it seems to prove that the capillary circulation is in a great measure independent of vital influences, and that its persistence is mainly due to physical agencies.

With a few observations on the mucous follicles situated on the upper surface of the tongue of the frog we shall conclude our relation of the capillary circulation, as witnessed in that organ. These follicles are glands reduced to the simplest possible amount of organisation; they are of a regularly spherical form, and transparent texture; they are situated in the mucous membrane of the tongue, to the thickness of which they are entirely confined, as proved by the fact that, when that membrane is dissected off, by means of a needle the glands are raised along with it. Into each of these glands may be seen entering it on one side, and quitting it usually on the opposite, one of the smallest of the capillary vessels, in which the blood corpuscles pass usually in single series, this vessel in its passage through the gland describes usually a tortuous course; and within it the blood corpuscles are seen to be in a state of increased and incessant activity, appearing to move, as it were, in a vortex, this appearance resulting from the curvatures described by the vessel. (See Plate VII. *figs.* 1, 2.)

It might be expected that, in a gland of such simple constitution, the exact process of secretion would be rendered apparent; in this expectation, however, we are doomed to disappointment, no action beyond that which we have already related being visible within it. An endosmotic action does doubtless take place between the contents of the gland and those of the vessel which permeates it, whereby a peculiar product is obtained from the blood, to be fashioned and assimilated by certain powers inherent in the gland itself, and the precise nature of which powers is unknown to us, and it is probable that it never will be revealed. Pass we now to the description of the circulation in the embryo of the chick, which possesses points of interest distinct from those observed in the tongue of the frog.

CIRCULATION IN THE EMBRYO OF THE CHICK.

The process by which the circulation in the embryo of the chick is displayed is one which requires considerable delicacy of manipulation; the care, however, which it is necessary to bestow upon it, for its successful exhibition, is amply repaid by the surpassing beauty of the spectacle which presents itself to the beholder. It is best seen in the third, fourth, and fifth days of the incubation of the egg.

For the purpose of showing it satisfactorily the egg should be broken at the side, and a portion of the shell cautiously removed, without at the same time raising with it the subjacent membrane (*membrana testæ*); this should next be peeled off with the same degree of caution as that with which the shell itself was previously raised.

Immediately beneath this membrane the yolk itself will be seen floating in the midst of the colourless albumen, and sustained in position by the beautifully spiral *chalazæ,* which proceeding from the yolk are fastened into that portion of the *membrana testæ* which corresponds with the poles of the egg-shell.

Imbedded in the surface of the yolk of an egg on the third, fourth, and fifth days of its incubation, the embryo will be visible, and issuing from its umbilicus will be seen the vessels which ramify in such graceful order through the membrane of the allantois.

The embryo is almost invariably placed uppermost in the yolk, so that it most generally presents itself beneath, whatever part of the shell has been broken. This position results from the lighter specific gravity, and is, moreover, facilitated by the spiral formation of the chalazæ.

The purposes fulfilled by this position of the embryo are obvious and striking, it being thus so placed as to receive directly the caloric which is continually emanating from the parent hen, and being also more immediately submitted to the influence of the oxygen of the air.

In an embryo then thus placed *in situ,* in the third, fourth, and fifth days of its development, and with the unaided sight, the rudiments of almost all the organs and members may be clearly recognised, the eye and the regular contractions of the heart, together with the vessels departing from it to ramify through the allantois, being particularly conspicuous. With a low power of the microscope the course of the blood in the vessels, together with the form and size of the white and red corpuscles, may be clearly distinguished.

The ramifications of the vessels in the allantois presents an arborescent distribution; their entire course may be traced from their commencement in the aorta to their termination on the border of the membrane of the allantois.

Now the great point of interest in the circulation of the chick is that the passage of the blood may be witnessed throughout; thus the blood expelled from the heart by the contraction of the ventricle into the aorta may be traced through this vessel, and all its subsequent divisions and subdivisions, until it reaches the ultimate arterial radicles, passes from these into the corresponding radicles of the veins, and from these again into the larger venous trunks, by which it is reconveyed to the heart, the circle of the circulation being thereby completed.

There are two ways in which the circulation in the embryo of the fowl may be viewed, either while it is still occupying its natural position on the surface of the yolk, and this I think is by far the most preferable method; or the embryo may be altogether detached from the yolk by means of an armed needle, and subsequently placed on a watch-glass filled with warm water at a temperature of 96°. During the operation of detaching the embryo, the egg itself should also be immersed in water at the temperature just mentioned. This latter process is one, however, of much nicety, and frequently fails in consequence of the rupture of some of the finer vessels, the blood becoming effused, the different parts of the embryo obscured, and a stoppage put to the circulation.

But it is not alone the contemplation of the circulation in the embryo of the chick which is so interesting and instructive; the study of the entire development of the ovum from its commencement to its termination reveals facts of the highest importance and full of wonder.

The examination of the blood of the embryo fowl is especially instructive, the mode of formation of the red corpuscles admitting of determination in a manner the most satisfactory.

In the red corpuscles contained in the blood of the embryo in the first days of its development, a remarkable variation of size will be detected, some of them being three or four times larger than others, and the smallest consisting almost entirely of a nucleus surrounded by a faint and delicate envelope. Between the two extremes of size every possible gradation is presented. (See Plate IX. *fig.* 1.)

This variation in the dimensions of the corpuscles becomes scarcely less apparent if they be immersed in water, in which they become perfectly spherical. (See Plate IX. *fig.* 2.)

A diversity of size almost as remarkable as that which exists between the red blood corpuscles of the embryo fowl will be observed also in those of the young frog which has but just emerged from its tadpole state. If a drop of the blood of this young frog be compared with that of a full-grown frog, the corpuscles in the former will be remarked to vary greatly in dimensions, while in the latter they will be seen to present a much greater uniformity of size. (See Plate IX. *figs.* 4, 5.)

Now, the inferences to be deduced from this great diversity of size are palpable, and are, first, that the red blood corpuscle is at its origin small, and only attains its full dimensions after a given period; and, second, that the nucleus is the part of the corpuscle which is first formed, the coloured investing and perfectly smooth portion of it being gradually developed around this subsequently. This view is inconsistent with the notion entertained by many that the red blood corpuscles result from the gradual assumption by the white globules of the characteristic distinctions of the red blood discs, for were this really the case we should be at a complete loss to account for the remarkable differences of size to which we have adverted.

A similar mode of development to that which has been described as belonging to the red blood corpuscles of the embryo fowl appertains also, I believe, to that of all the Oviparous Vertebrata.

The development of the coloured blood corpuscle of the Mammalia, I conceive to agree also with that of the other Vertebrata in the fact of their being small at first, and subsequently and gradually attaining their normal proportions, but to differ from that of the Oviparous Vertebrata in not being developed around a central nucleus.

DISSOLUTION OF BLOOD CORPUSCLES.

But if the blood of the embryo fowl is well adapted for the study of the origin and development of red blood corpuscles, that of the adult fowl is no less fitted for ascertaining their end and final *destination.*

Some observers have entertained the idea, already expressed in this work, that the older blood discs become melted down in the *liquor sanguinis,* and thus, by their dissolution, increasing the amount of fibrin held dissolved in that liquid. To the adoption of this notion they were driven because they were unable to dispose of the red blood disc in any other way, and which other facts had made apparent to them could not be regarded as persistent structures.

In proof of the accuracy of this statement respecting the melting down of the corpuscles, they had not, however, a particle of direct evidence to adduce. I will now proceed to show that the view referred to may be substantiated by positive observation.

In almost every drop of the blood of an adult fowl a number of certain pale and usually colourless corpuscles will be seen, having a nucleus of the same size and structure as that of the ordinary red blood disc distinctly visible in the midst, the investing portion of each corpuscle at the same time being invariably smooth and destitute of granules.

These corpuscles vary in size, in form, and in colour; the larger ones, which are equal in dimensions to the fully developed blood discs, usually retain a faint coloration, and are invariably of an oval form, while the smaller ones, many of which consist of merely a nucleus and a closely fitting envelope, are perfectly colourless, and for the most part, although not always, spherical. (See Plate IX. *fig.* 3.)

Now there is no difficulty whatever in detecting these pale and mostly spherical corpuscles with a good instrument, nor is there the slightest danger of confounding them with the white corpuscles, which are also to be seen retaining their uniformly molecular aspect.

The corpuscles just described exist not merely in the blood of the adult fowl, but they may be detected, with similar facility, in every Oviparous Vertebrate animal the blood of which I have examined; and they abound in the blood of tritons and frogs. (Plate IX. *fig.* 5.)

But further there may be detected in the blood of adult Oviparous Vertebrata, not merely the delicate and pale corpuscles referred to, but also numbers of naked nuclei, that is, of nuclei deprived of all trace of investing membrane. (See Plate IX. *figs.* 3 and 5.)

These nuclei should, however, be examined with care, and a nice adjustment of the object-glass; for it will be found, on close examination, that many of them, though appearing at first sight to be naked, are not really so, but are invested by a scarcely perceptible envelope.

Now these large and slightly coloured oval corpuscles, the smaller perfectly colourless and mostly spherical ones, and the naked nuclei, represent progressive states of the dissolution of the red blood disc.

When first I noticed these pale corpuscles and nuclei, I was disposed to think that they represented stages in the upward development of the red blood disc: this opinion was, however, dispelled, by observing that the pale and colourless corpuscles often exceeded greatly in size the smaller true and coloured blood corpuscles.

There is one circumstance connected with these pale corpuscles which does not appear to admit of any very satisfactory explanation, viz. their occurrence on the field of the microscope in groups.

A word or two as to the seat or locality in which the work of development of blood corpuscles, and subsequent dissolution of them, is conducted. Physiologists appear always to have been on the look-out for some organ of the body, the especial purpose of which in the animal economy they conceived should be the elaboration of the blood corpuscles; and some of them, as Hewson and Donné, not knowing well what office ought to be assigned to that much discussed organ, the spleen, have on various grounds considered it to be the laboratory in which the work of development is carried on. Of the dissolution of the red blood discs no definite or decided observations hitherto appear to have been made by any observer.

Observation has convinced me that the development of blood corpuscles is not assigned to any particular organ of the body, but that it occurs within the blood-vessels during the whole course of the circulation and of life. During the first formation of the blood in early embryonic life, the corpuscles are said to be formed in the cells, which by their union with each other give origin to the capillary vessels.

Further, it is probable, that, while it is in arterial blood that the work of development of blood corpuscles is most active, it is in the venous fluid that the converse work of dissolution is mainly effected.

The development of blood corpuscles is also most active in very early life, when growth is rapid, and it is likewise more active than ordinary in adult existence, after hæmorrhages, and in persons of the plethoric diathesis. In like manner it may be presumed that the dissolution of red blood corpuscles proceeds more quickly in anæmic conditions of the system, and in old age, while at the same time, at the latter period, development of new corpuscles is more tardy.

It is now hoped that a more satisfactory explanation of the *origin* and *end* of the red blood disc has been given than it was feared, when the writer first approached the consideration of these difficult, though most important, questions, it would have been in his power to have afforded.

VENOUS AND ARTERIAL BLOOD.

Venous and arterial blood differ in certain important respects from each other; arterial blood is of a brighter colour, and coagulates more firmly than that which is venous. The difference in colour is due to the presence in the former of oxygen, and in the latter of carbon in a state of combination not yet well determined. Venous blood, when exposed to the action of oxygen, soon acquires the vivid red colour of arterial blood, and this, when submitted to the influence of carbonic acid, as speedily assumes the dark hue of venous blood.

The greater or less firmness in the clot formed is owing to the different amount of fibrin contained in the two fluids, and which is greatest in that which is arterial, the coagulum of which, therefore, possesses the greatest density. The differences detected by the microscope in the blood corpuscles of arterial and venous blood are scarcely appreciable. Gerber states that the "tint of colour exhibited is various; bright in the globule of arterial blood, dark red and somewhat streaky in that of venous blood:" this difference of colour, which doubtless exists, it is easier to infer than positively to demonstrate by means of the microscope. While arterial blood is richer in salts, venous blood contains a greater proportion of fatty matter.

There are several substances which effect a change in the colour of the blood: thus oxygen, the concentrated solutions of salts with an alkaline base, and sugar turn dark venous of a bright florid or arterial red, this reddening being accomplished by the salts and sugar, even when the blood is placed in a vacuum, or an atmosphere of hydrogen, nitrogen, or carbonic acid gases.

Newbigging[*] hath also remarked that venous blood takes the tint of vermilion in a cup, at those situations at which it is painted with the green oxide of chrome, and Taylor[†] has confirmed the observation that the colours which contain the oxide of chrome brighten the tint of blood.

On the other hand, bright or arterial blood is darkened, or even blackened, by contact with carbonic and oxalic acids, and by its admixture, according to Henle, with distilled water.

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[*] Edinburgh New Philosophical Journal, October, 1839.

[†] Lancet, February, 1840.

Sulphuric acid, and other acids which are agitated with the blood, change its colour from red to *blackish* brown.

The nitrous and nitric oxides cause vermilion blood to take a deep purple tint.[*]

The power possessed by those substances which brighten the colour of dark venous blood is supposed to be derived from the oxygen which they contain, and by means of which a chemical transformation in the condition of the red element of the blood, the *hematine*, is effected, a portion of oxygen being absorbed during the change of colour. Those substances, however, which cause arterial blood to assume the tint of venous blood are presumed to exert their influence by means of the carbon of which they are compounded, and a portion of which becomes imbibed during the work of transmutation.

Henle, nevertheless, considers that these several alterations of colour arise rather from mechanical than chemical causes, and that they depend upon the state of aggregation of the particles of the colouring matter, these being differently disposed according to the nature of the reagent employed.

Thus Henle remarks[†], "It is evident that the colour of the blood is brightened under the influence of substances which oppose the dissolution of the hematine in the serum and maintain or re-establish the flat form of the corpuscles, as the concentrated solutions of salts and of sugar, while pure water, which dissolves the colouring matter and causes the corpuscles to swell, deepens the colour of the blood."

Hamburger[‡], according to Henle, has even observed that weak solutions of the chlorides render the colour of the blood deeper, while their concentrated solutions make it pass to vermilion.

Again, according to the observations of Schultz, it would appear that the red blood corpuscles are flattened by the action of oxygen, while the effect of the application of carbonic acid is to cause them to swell up, and assume a more or less globular figure.

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[*] Henle, Anatomie Générale, tome premier, page 471.

[†] Loc. cit. page 471.

[‡] Hamburger, Exp. circa Sanguinis Coagulationem, pp. 32. 42.

On this fact Henle reasons thus: accompanying these changes of form there are alterations in the state of aggregation of the colouring matter of the corpuscles; thus, in oxygen, or in any saline solutions, the plasma remains clear and colourless, the blood discs being flattened, and the colouring matter contained within them condensed, while in carbonic acid or water the plasma becomes coloured by the escape of a portion of the hematine from the corpuscles, which swell up, and assume a form approaching more or less the globular.

Now the difference in colour between venous and arterial blood Henle maintains may be accounted for by reference to the form of the corpuscles, and the consequent condition of the particles of the colouring matter.

And it is also by reference to the state of the colouring matter that Henle accounts for the fact that blood which has once acquired a very dark colour is thereby rendered incapable of re-assuming the bright hue of arterial blood on the application of oxygen or saline solutions, because, he says, that the pigment which had escaped into the plasma, under the influence of the carbonic acid, cannot be made to enter into the corpuscles again, when by means of oxygen they are again flattened.

The colour of the blood, then, according to Henle, depends upon the single fact of the form of the corpuscle, and that this colour is so much the more bright as these are flat.

Finally, in support of his theory, Henle refers to changes of colour presented by certain inorganic substances from an alteration in the state of aggregation of its constituent particles: thus it is well known that the iodurct of mercury recently sublimed is yellow; in cooling its colour passes to scarlet, and pressure determines this change in an instantaneous manner.

Such is Henle's *mechanical* theory of the changes of colour experienced by the blood on the addition of reagents, a theory which, however ingenious it may be, I deem to be insufficient to account for the very remarkable alterations of colour to which the vital fluid is subject.

The changes of colour of dark blood to a vermilion hue, and of this again to the deep tint of venous blood, admit of a chemical explanation being given, the essential element of the former change being oxygen gas, and of the latter carbonic acid gas. Thus, even the remarkable effect of the application of the chlorides may be accounted for by reference to the well-known operation of chlorine as a bleaching agent, viz. through the power which it possesses of depriving water of its hydrogen, and altering the state of combination of the oxygen.

With respect to the observations of Schultz on the effect of carbonic acid and of oxygen in altering the form of the red blood corpuscles, and on which fact the entire of Henle's theory rests, I would observe that, in conjunction with Mr. Miller, the gentleman who manifests so much of patience, skill, and intelligence in the execution of the drawings of this work, and who is moreover an excellent chemist, I have made many experiments with the view of ascertaining the power possessed by the former reagent in modifying the form of the elliptical corpuscles of the blood of the frog, the blood being in some cases submitted to the direct action of the gas, and in others the animal itself being subjected to its influence.

The result of these experiments, on my mind, is the conviction that the effect of this gas on the figure of the corpuscle is not appreciable. I am therefore disposed to allow but little weight to the mechanical theory of the changes of colour experienced by the blood.

Venous blood does not present precisely the same tint of colour or the same characters in all parts of the system: thus the blood found in the vena porta is deeper in colour than any other venous blood, and, according to Schultz, it does not redden either on the application of oxygen gas or of salts, and does not coagulate, or gives but a divided clot; it is richer in water, in cruor, and in fat, and poorer in albumen, than ordinary venous blood.

It would be a point of much interest to determine whether arterial or venous blood contains the greatest number of blood corpuscles. The experiments which have hitherto been made with the view of determining this question are most unsatisfactory, and contradict each other.

MODIFICATIONS OF THE BLOOD CORPUSCLES THE RESULTS OF DIFFERENT EXTERNAL AGENCIES.

Peculiar Modification the Effect of commencing Desiccation.

If the red corpuscles be examined a few minutes after their abstraction from the system, in a drop of blood which has been spread out between two plates of thin glass, it will be seen that many of them, and especially those which are situated near the margin of the drop, present an appearance very different from that which belongs to them in their ordinary and natural condition. They now no longer exhibit the flattened form with the central depression, but have become converted into little spheres, the surface of which, instead of being smooth, is now rough and tuberculated. (See Plate I. *fig.* 5.) Blood corpuscles thus changed have been compared to mulberries in appearance. This alteration is supposed by Donné to depend upon commencing desiccation, and to arise from deficiency of serum, the mulberry-like globules being but imperfectly bathed in that liquid. No very satisfactory explanation of the exact nature of the change has as yet been given. MM. Andral and Gaverret * suppose that the mammillated appearance of the corpuscles arises from the adherence to the surface of the globules, of a number of the exceedingly minute molecules of the fibrin; this explanation is probably more ingenious than correct. If a number of the altered globules be carefully and closely examined, it will be remarked that they do not all exhibit precisely similar appearances; that in some globules, for instance, it will be observed that the contour is but slightly broken or indented, that in others the indentations of the surface are more considerable, and the small spaces between them consequently more prominent; and again in other globules, and which are indeed by far the most numerous, it will be obvious that the whole surface has become distinctly tuberculated, each tubercle, of which there are several to each globule, appearing to be of a spherical form, and resembling a minute bubble of some gas, probably of oxygen, or carbon, according as the blood is arterial or venous. That they are really of a gaseous nature is proved, I think, by the fact of their gradual formation as well as dissipation. M. Andral states, that in blood which has been deprived of its fibrin, the corpuscles never exhibit the peculiar granulated or tuberculated aspect which we have described, and this fact he adduces in support of the opinion entertained by him, that this peculiar condition of the globules is due to the accumulation on their surface of the molecules derived from the fibrin.

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* Essai d'Hemalogie Pathologique, par G. Andral, page 23.

Mr. John Quekett is also of the opinion that this peculiar condition of the blood globules of which we have been speaking, is occasioned by the adherence to their edges of granules which he considers to be derived from the interior of the corpuscles themselves. See "Observations on the Blood Discs and their Contents," Microscopic Journal, vol. i. p. 65. For further observations on this granulated appearance of the corpuscles, see Part I. p. 31.

MODIFICATIONS THE RESULTS OF DECOMPOSITION OCCURRING IN BLOOD ABANDONED TO ITSELF WITHOUT THE BODY.

In blood abandoned to itself and exposed to atmospheric influences, changes of form and appearance speedily begin to manifest themselves in the red corpuscles. These changes occur in regular order; they first become wrinkled, deformed, and tuberculated; they next lose their flattened and disc-like shape, becoming globular and smooth; their colouring matter escapes from them, and they present a livid hue. In this condition they are with difficulty discoverable in the blood;

finally, they dissolve, and all traces of them disappear. These successive changes are all produced in the course of a very few hours: the exact period, however, varies with the temperature of the atmosphere and actual condition of the blood when extracted from the system.

MODIFICATIONS THE RESULTS OF DECOMPOSITION OCCURRING IN BLOOD WITHIN THE BODY AFTER DEATH.

The changes which we have described as occurring in blood abandoned to itself without the system, take place likewise in the red corpuscle of that which is contained within the body after death, and this even with a greater degree of quickness than in the former case; the time, however, bears a relation to atmospheric conditions, to temperature, as well as, especially, to the nature of the malady to which the patient has succumbed. If the affection which has occasioned death be of a nature to exhaust profoundly the vital powers, if it be a chronic disease of long duration, as a typhoid fever, the period requisite for the production of these changes will be very short; so brief, indeed, that the alterations may be detected in the corpuscles almost immediately after the extinction of life. It is of much importance that the changes resulting from decomposition, and which occur in the dead body, should not be confounded with real and pathological alterations of the red corpuscles.

CAUSES OF INFLAMMATION.

Exciting Cause.

The fact which has been alluded to in the preceding pages, of the accumulation of the white and red corpuscles in the tongue and web of the frog as a consequence of the application of irritation, bears a close relation to the phenomena of inflammation, and shows that the exciting cause of inflammation, whatever it may be, such as a blow, exposure to cold, burns, scalds, or the application of irritating substances, acts usually through the medium of the nervous system, the impression produced on it impinging upon the structures to which the ultimate nervous fibrillæ are distributed, viz. the vessels in the which a series of results ensue which together constitute the condition of inflammation.

Proximate Cause.

When the white and the red corpuscles of the blood accumulate in the capillaries of a part in normal quantity, those vessels may be considered to be in a state of "vital turgescence;" when, however, they are present in those vessels in abnormal proportion, then the capillaries may be said to be in a state of "inflammatory turgescence."

Now the term "congestion" indicates a condition of the vessels intermediate between vital and inflammatory turgescence, and which may be denominated "congestive turgescence."

In vital turgescence, a phrase which indicates the condition of the vessels in a state of normal nutrition, the capillaries are slightly increased in calibre, and are pervaded by an unusual, though perfectly normal number of corpuscles, both red and white, but especially of the latter, some of which adhere to the walls of the vessels.

In congestive turgescence, or in congestion, the calibre of the capillaries is more considerably increased in size, and a greater and abnormal number of white and red corpuscles, especially the former, are collected in the vessels. These corpuscles, if the turgescence terminates in resolution without advancing to the condition of inflammation, do not undergo any structural changes, but enter again into the circulation, their removal being determined by the discontinuance of the exciting cause, and by the *vis a tergo* of the circulation, which drives the corpuscles onwards.

Lastly, in inflammatory turgescence the diameter is very considerably enlarged, and their interior is filled with a very greatly increased and abnormal quantity of white and red corpuscles, these accumulating to such an extent as either to seriously obstruct, or altogether destroy, the circulation in those vessels This condition of the vessels is always accompanied by certain structural alterations, which affect not merely the corpuscles themselves, but also the vessels and parts adjacent to them; these alterations being merely attributable to the impediment presented to the onward progress of the blood in the capillaries by the accumulation in them of the blood corpuscles.

We now know that the proximate cause of inflammation consists in an abnormal accumulation of the corpuscles of the blood in the minute capillary vessels, and which accumulation we perceive must inevitably impede the function of the part in which the vessels are thus surcharged, alter its structure, and finally tend to a sympathetic disturbance of the entire economy. For this discovery we are indebted to the microscope. It will thus be seen that some of the ancient hypotheses in reference to the proximate cause of inflammation were not so very far wrong, and that most of them recognise the fact that it is the capillary vessels and blood corpuscles which are mainly concerned in the production of the phenomena of inflammation.

Finally, inflammation may, like congestion, terminate in resolution; but, unlike congestion, it always leaves permanent traces of its visitation, the resolution being but incomplete. It may terminate, also, in "hepatization," or in "purulent infiltration." The fibrin of the blood is the chief agent in producing the consolidation of the structure known by the term hepatization, while it is the white corpuscles analogous to those of the blood, as will be seen hereafter, that give rise to the purulent formation.

PATHOLOGY OF THE BLOOD.

We come now to the consideration of the most important division of our Chapter upon the blood, viz. that which treats of the pathological changes which that fluid undergoes, and a full and clear understanding of which is so necessary to the safe and successful treatment of disease.

These pathological alterations are numerous, and engage not merely the solid constituents of the blood, the white and red corpuscles, but also its fluid elements, the fibrin and the albumen; the abnormal conditions of each of which principles of the blood we shall find to be accompanied by a distinct train of morbid phenomena. It may be said that the fibrin and the albumen being entirely of a fluid nature, and not holding solid particles of any magnitude in suspension, they ought not to be considered in a work devoted to microscopic anatomy. We shall find, however, that these several constituents of the blood are so intimately associated that, in order to understand any one of them fully, it is necessary that we should possess a knowledge of the others also, and therefore I consider that their discussion comes within the legitimate scope of this work.

For much of our knowledge of the pathology of the blood we are indebted to the united researches of MM. Andral and Gavarret, to whose valuable essay we shall have occasion hereinafter to make frequent reference.

Pathology of the Red Corpuscles of the Blood.

The scale of the red corpuscles of the blood, relative to that of the other elements, varies considerably, even in states of health. The mean proportion of red corpuscles is estimated by MM. Andral and Gavarret at 127 in every thousand parts of the vital fluid. This scale may, however, be elevated to 140, or depressed to 110; the variations in the quantity of the red globules within these limits being compatible, however, with a physiological or healthy condition of the blood, although the higher scale, 140, is allied to a state of plethora, while the lower, 110, borders upon the opposite state, of anæmia, and both of which may be regarded, if not as diseases in themselves, at least as powerful, auxiliary, and predisposing causes of many morbid conditions of the system.

Increase in the Number of the Red Corpuscles.—Plethora.

An increase in the number of the red corpuscles of the blood exists in that condition of the system which has been denominated the plethoric, and which increase constitutes its chief element. The authors already cited found the mean proportion of the red globules in the thirty-one cases in which the blood was submitted to examination, to be in every thousand parts 141; the minimum 131, and the maximum 154. With this increase in the number of the red corpuscles, it was not found that any other element of the blood had become either augmented or diminished.

The symptoms which indicate the existence of plethora, whether they be organic, or functional and mental, all admit of a ready and satisfactory explanation by a reference to the increased quantity of the red corpuscles.

The existence of a state of plethora implies high vital powers; there seems to be in the plethoric, as it were a superabundance of life, and which is imparted to all the parts and organs of the system alike. The plethoric diathesis would appear to be more frequently hereditary than acquired, and no degree of high and nutritious feeding will induce it in the system of some persons, although an opposite or anæmic state may be produced in all by the abstraction of a proper quantity of suitable nourishment.

The general symptoms which characterise the plethoric diathesis, are a well-developed muscular system, voluminous thorax, a deep-coloured skin, and a ruddy complexion; coinciding with these physical and outward appearances, we find much functional activity to exist, the respiration is free and unembarrassed, the digestion quick and active, the pulse is full and strong, and the motions of the body are performed with celerity and power. This functional activity appertains also to the operations and emotions of the mind; the plethoric is quick in thought, hasty and violent in temper.

The injected skin, and the brilliant complexion, are to be explained by reference to the increased quantity of the red corpuscles which circulate in the blood, and which alone are the seat of colour, while the great organic development and the functional and mental activity depend partially upon the greater amount of oxygen of which the blood corpuscles are the carriers to all parts of the system, and which is so essential to the vigorous performance of the vital processes and manifestations.

The characters exhibited by blood which has been withdrawn from the system are likewise consistently explained by reference to the augmented quantity of the red blood corpuscles; thus the blood in plethora, immediately on its abstraction, is observed to be of a deeper colour, and the clot formed subsequently by its coagulation of a larger size; this, although voluminous, is of mean density, and never exhibits the buffy coat, which circumstances are accounted for by the fact that, as already remarked, in the blood of plethoric persons there exists necessarily no excess of fibrin.

Accompanying the plethoric condition, and dependent upon it, we have frequently a number of grave pathological manifestations, apoplexies, hæmorrhages, congestions, vertigos, noises in the ears, and flashes of light before the eyes; all of which are most generally greatly relieved by venesection, which withdraws from the system a portion of the superabundant red blood corpuscles.

Decrease in the Number of the Red Corpuscles.—Anæmia.

The term anæmia indicates a state of the system the very reverse of that which obtains in plethora: in it the red blood corpuscles, instead of being in excess, are greatly below the physiological standard. The authors quoted found, in sixteen cases of commencing anæmia, the mean of the red globular element of the blood to be 109; and in twenty-four examples of confirmed anæmia, 65; that is, almost one-half less than the standard which belongs to health. In one case of anæmia in the human subject, M. Andral found the scale to descend so low as 28; a depression which one would scarcely suppose to be compatible with life.

In spontaneous anæmia it is stated, that it is the globules alone which are affected, and that in it, as in plethora, the other elements of the blood undergo neither augmentation nor diminution: in accidental anæmia, however, resulting from direct losses of the vital fluid, the normal standard is of course disturbed; for in hæmorrhages, and especially in first bleedings, it is chiefly the globules which escape, and this would lead to the relatively higher scale for the fibrin.

As anæmia depends upon a condition of the blood the very opposite of that which exists in plethora, the symptoms also in these two constitutional conditions are the reverse of each other; instead of the vascular and injected skin, we find it to be livid and exsanguine, these appearances extending also to the mucous membranes; in place of the accelerated functions, we notice that the vital actions are sluggishly performed, and that the mental powers are feeble.

The blood abstracted from the system exhibits a paler tint than is usual, and the clot is small and floats in the midst of the serum, which is very abundant; small, however, as the crassamentum is, it is yet of considerable density, as might be expected from the remark which has already been made, viz. that the fibrin exists in its normal proportion, and therefore is in excess over the globular element of the blood which is deficient; it is for the same reason also that we frequently notice upon the surface of the clot the buffy coat: the density of the clot, and of the crust which covers it, are so much the more marked as the anæmia is considerable.

The existence of the miscalled *inflammatory* crust in anæmic states has long been known, although not satisfactorily accounted for.

The pathological disorders to which anæmia gives origin are numerous: the general debility, the disordered digestion, the difficult respiration, the palpitations of the heart, the faintings, are well remembered.

There is a state of the system, well described by Andral, which simulates plethora, but which is really allied to anæmia, and to which the term *false* plethora might be given; in this we have the injected skin and many other indications of plethora; it is to be diagnosed, however, by means of the constitutional disturbances which coincide with those of ordinary anæmia.

It is in anæmic conditions of the system that we detect the remarkable *bruit de soufflet,* in reference to which Andral in his essay on the blood has instituted some useful researches, the chief result of which is the establishment of the fact, that the intensity and persistence of the *bruit* is in exact proportion to the severity of the anæmia.

In pregnancy we have a slight example of an anæmic condition of the blood, and in chlorosis we see anæmia to prevail with various degrees of severity. In phthisis the scale of the red corpuscles is likewise much reduced, but not to the extent to which its reduction is witnessed in chlorosis; and this is the more remarkable from the circumstance that in the former disease it is those organs which are affected, between which and the red corpuscles a close connection exists. In cancer also the number of the blood corpuscles is reduced: in phthisis the diminution precedes and accompanies the whole course of the affection, while in cancer it occurs only at an advanced period of the disease, and arises principally from the continual losses of blood to which cancerous patients are so subject. In disordered states of the system purely nervous we find also the red element of the blood to be deficient. The scale of the red globules in a number of cases in which the blood of phthisical patients was submitted to examination oscillated between 80 and 100.

Increase in the Number of the Red Corpuscles under the Influence of Recovery and of certain Medicinal Agents.

Under the influence of recovery the red blood corpuscles increase in number, and have a tendency to attain to their physiological standard, which, when reached, they may even exceed, until at length they mount up to the scale which denotes the existence of the plethoric condition.

Certain medicinal substances exhibit likewise much influence in increasing the number of the red corpuscles; of these the most remarkable is iron, under the effect of which remedy the pale complexion of the chlorotic will be seen gradually to acquire the tone and colour indicative of health and strength.

Effect of Disease upon the White Corpuscles.

The white corpuscles of the blood have not hitherto received that amount of attention which has been bestowed by so many observers upon their associates the red corpuscles; indeed, it is only in these later times that their investigation has been pursued with that degree of care, which, from their importance, they so well merit, and observations are still wanting upon their condition in states of disease. It has already been remarked that an increase in their number has been frequently observed to occur in various diseases, and especially in such as are accompanied by suppuration and great exhaustion of the vital powers. Of the precise cause of this increase no very satisfactory explanation has been offered, and the following attempt at an explanation is presented to the consideration of the reader with much hesitation. In most serious disorders the function of nutrition and assimilation is more or less impeded. Now, supposing that these white corpuscles are essentially connected with nutrition, and that while the cause which determines their formation still continues in operation, that which regulates their assimilation is suspended, there would result, as an inevitable consequence, an accumulation of the white corpuscles in the blood.

Deficiency of Fibrin in Fevers, as in Typhus, Small-pox, Scarlatina, Measles.

The important researches of MM. Andral and Gavarret establish the fact, that, in that much debated class of maladies, fevers, there is a deficiency in the blood of its spontaneously coagulable element, the fibrin. In the Essai d'Hématologie no scale of the diminution in the amount of fibrin is given; it is shown, however, that in some fevers, and especially in the commencement, the deficiency of fibrin may be but small; and that in others, particularly when symptoms of putridity have manifested themselves, and which may ultimately complicate all fevers, the loss of fibrin is considerable, and further that the intensity of the symptoms is in direct relation to this loss, being great when the diminution of fibrin is also great.

It is not to be understood, however, that the deficiency of fibrin constitutes the essence or real and specific cause of fever; for this we must look to some other agent or fact, probably to the contamination of the general mass of the blood by the imbibition of some deleterious and subtle miasma. That the deficiency in the amount of fibrin is not the cause of fevers we find to be proved by the facts that this class of maladies attacks persons of every possible variety of habit and constitution, and in many of whom, at the onset of the disorder, no deficiency of fibrin can be detected; and the same view is likewise confirmed by the circumstance which must have attracted the attention of every physician, viz. that the primary condition and inherent powers of the system determine and control but to a comparatively slight extent the course which the malady may take, and which course seems to be dependent upon the nature and quality of the infecting agent itself. The inference, then, which may be derived from the fact that a deficiency of fibrin exists in the blood of persons afflicted with fever, is, that the tendency of the cause of fever, a miasma, or whatever else it may be, is to occasion a depreciation of the physiological standard of the fibrin in the blood, and not that the deficiency is in itself the exciting cause of fever.

Between this diminution in the normal proportion of the fibrin and the various hemorrhages, which are so often observed to complicate fevers of all kinds, a co-relation doubtless exists, although the precise manner in which this deficiency leads to such a frequent recurrence of hemorrhage is not clearly understood, and the only way in which this can be explained is by the supposition that in fevers from the cause assigned, viz. the small quantity of fibrin, the solids generally, and the blood-vessels in particular, lose a portion of their solidity, and readily give way to the force of the fluid contained within them.

The hemorrhages referred to are frequently observed in small-pox, in which the blood is effused into the pustules; in scarlatina, in which fluxes take place from various parts of the body; and in typhus, in which we have frequent buccal hemorrhages, and the formation of petechiæ.

Cotemporaneous with this diminution in the amount of fibrin, we do not find that any other element of the blood is constantly affected, although it occasionally happens that the red globules are in excess.

The clot in typhus, in which, of course, the deficiency of fibrin is considerable, is large, filling almost the entire of the vessel which contains it; is soft, being readily broken up on the slightest touch; it is flat, and ill-defined, and the serum in which it floats is of a reddish colour.

The flat form and softness of the clot is to be explained by reference to the diminished amount of fibrin, while its great size is accounted for by the imperfect expression of the serum from the crassamentum, as well by the fact that the red corpuscular element of the blood exists usually in its normal proportion, and is not unfrequently found to be even in excess.

The important distinction which exists between symptomatic or organic fevers, and idiopathic or non-organic fevers, is very essential to be borne in mind, for in the former no such deficiency of the fibrin exists as we have seen to belong to the latter; the blood in inflammatory affections, as will be shown hereafter, exhibiting a state of its spontaneously coagulable element the very reverse of that which belongs to the blood of idiopathic febrile disorders. It must also be recollected, that an idiopathic fever may, during its progress, become complicated with organic lesion, a circumstance which would affect materially the amount of fibrin in the blood, its effect being to increase the proportion of that constituent.

Increase in the Amount of Fibrin in Inflammatory Affections, as in Pneumonia, Pleuritis, Peritonitis, Acute Rheumatism, &c.

While in the class of febrile disorders, of which we have just spoken, a deficiency of the fibrin in the blood exists, in another series of affections, the inflammatory, this element is found to be in excess. To constitute an inflammation, however, two concurrent circumstances are required; it is not alone necessary that the proportion of the fibrin should be increased, but also that an organic lesion should have occurred, these two pathological alterations bearing a close and constant relation with each other.

Since, then, the spontaneously coagulable element of the blood in the one class of disorders, viz. fevers, is deficient, while in the other class, inflammations, it is superabundant, it follows that the specific cause which gives origin to these two orders of maladies operates in two opposite directions; its tendency in the one being to diminish, and in the other to augment the quantity of fibrin.

The law of the increase in the quantity of fibrin in inflammatory disorders manifests itself under very remarkable circumstances; such, indeed, as one would imagine to be but little favourable to its manifestation: thus, in the case of an inflammation supervening on typhus, in which we have seen that the normal scale of fibrin undergoes a depression, a disposition to the augmentation of that scale will become apparent. In the example of typhus complicated with local lesion, we have two forces in operation; the tendency of one of which is to diminish the amount of fibrin, and of the other to increase that amount; and the result of which forces operating at the same time is the production of a mean effect.

The proportion of fibrin in man in a state of health is estimated at 3 parts in every 1000 of the blood. In a case of inflammation occurring in the course of typhus, the scale was found to be $5\frac{1}{2}$ in persons affected with chlorosis, in which we have seen that it is the globular element of the blood which is deficient, and attacked with capillary bronchitis, acute articular rheumatism, erysipelas, and pneumonia, the proportion varied from 6 to 7 and 8; in acute inflammations occurring in healthy individuals, it oscillated between 6 and 8; and in a less number of cases between 7 and 10. The highest scale recorded by M. Andral is 10: and this was met with only in pneumonia, and acute rheumatism, while the lowest was only 4: this scale borders upon that which is regarded as normal, and is encountered only in sub-acute inflammations.

It is not merely, however, in pure and extensive cases of inflammation that the proportion of fibrin in the blood becomes augmented, for we find it also increased in every organic affection which is accompanied by even a slight degree of inflammation: thus in phthisis, at the period of the elimination of the tubercle, as well as in cancer, in which there is inflammation of those portions of the organs, the seat of the disease which immediately surround the tuberculous, or cancerous deposit, we have also an increased amount of fibrin in the blood. This increase, even in the last periods of the disorder in phthisis, rarely exceeds 5 parts inthe 1000. The blood in consumption exhibits then not merely an excess of fibrin, but also a depreciation in the proportion of its red element to the extent shown under the heading *Anæmia.*

There is one condition of the system compatible with a state of health, under which also the proportion of the fibrin in the blood is augmented, and that is gestation. It is stated, however, by M. Andral, that this increase manifests itself only in the three last months of pregnancy, previously to which the scale of the fibrin is found to be slightly depreciated. This augmentation goes on increasing from the sixth to the ninth month, and is greatest at the completion of the term of utero-gestation, which fact offers a satisfactory explanation of the reason of the liability to inflammatory attacks on the part of women recently delivered. The condition of the blood, therefore, in the last periods of pregnancy is allied to that state of the vital fluid which is especially indicative of the existence in the system of an inflammation.

The characters presented by the clot in inflammation are almost the reverse of those which distinguish it in fevers. It is of moderate size, of firm texture, frequently cupped, and its surface usually covered with the buffy coating of a variable thickness. The theory of the formation of this peculiar layer has already been entered into, and the various circumstances under which it has been encountered have now been noticed; we have seen that it occurs in two very different states of the system, that it is present on the clot of blood abstracted in anæmic conditions, as well as on that formed in blood withdrawn in inflammatory states; in the first of these there is, in comparison with the red corpuscles, a relative increase in the proportion of the fibrin, and in the second, a positive augmentation of that important element of the blood.

The fact of the existence of a superabundance of fibrin in the blood in inflammatory states may be in some measure inferred from the circumstance of the escape in inflammation of a portion of its fibrin, and which doubtless is attended with a certain degree of relief to the organ affected. In many cases, however, it is not alone the fibrin which escapes, and which is liable to become organized, but also the other constituents of the blood, its red and white corpuscular element, (the latter probably constituting the pus which in certain severe cases is met with,) and the serum; these constituents, however, are not susceptible of organization, and are, where recovery takes place, removed from the situation of their effusion by absorption.

The discovery of the fact, that in inflammatory disorders an excess of fibrin is formed, explains the exact manner in which blood-letting proves so serviceable, viz. by removing from the system directly a portion of its superabundant fibrin; so powerful, however, is the cause which determines the formation of this excess of fibrin, that in spite of the most energetic and frequent use of the lancet, the scale of that element of the blood will frequently, and indeed does generally, ascend.

Condition of the Blood in Hemorrhages.

Reference has been made to the frequent occurrence of hemorrhages in two very distinct classes of disorders, the plethoric, and the febrile. In the first, we have seen that it is the red element of the blood which is absolutely in excess over the other constituents of that fluid, while, in the second, it is the fibrin which is deficient, the globules being unaffected, and existing usually in their normal proportion. Thus, relatively to the fibrin in both series of affections, the globules are always in excess, in reference to the first series, the plethoric, being absolutely so, and to the latter, relatively superabundant.

While it is this excess of the red globules which probably determines the occurrence of hemorrhages, the nature and degree of these losses of blood are modified by the amount of fibrin which that fluid contains. Thus the character of the hemorrhages occurring in plethoric individuals is very different from that encountered in persons labouring under fever in most of its forms; in the first, we have copious epistaxes and the effusion of blood into the substance of the brain, constituting sanguineous apoplexy; in the second, almost any tissue of the body may be the seat of the effusion; the blood may escape from the nose, the gums, the throat, or the bowels, or it may be poured out beneath the skin in patches, constituting petechiæ, which we meet with so frequently in severe cases of typhus, and in scurvy. The hemorrhages to which the plethoric are liable are for the most part salutary, while those which take place in fevers are as generally prejudicial. The treatment to be adopted in the two cases is very different; in the one it may be necessary to have recourse to venesection, with the view of lessening the scale of the red globules, and in the other such a mode of proceeding would in all probability be fatal, the object in it being to restore to the blood its normal proportion of fibrin.

The distinction which has here been dwelt upon between the hemorrhages to which the plethoric are exposed, and those to which the system is obnoxious in febrile disorders at an advanced period of their attack, corresponds with the division of hemorrages into active and passive; the former, or sthenic type, denoting the active, and the latter, or asthenic, the passive hemorrhages.

In disorders in which usually we have no excess of the red globules, but in which the fibrin invariably exceeds its usual quantity, as the inflammatory, and in affections in which the red element is constantly deficient, but in which the fibrin retains its proper proportion, as in anæmic states, and especially chlorosis, we find that hemorrhages are of very rare occurrence, and hence again we are led to recognise the accuracy of the statement, that the essential conditions for the occurrence of hemorrhages are an excess of the red corpuscles, as well as in certain cases a deficiency of the spontaneously coagulable element of the blood, viz. the fibrin.

Between the condition of the blood, in which there is a deficiency of fibrin, as in most fevers, and that state of the system which occupied so much of the attention of the ancient humeral pathologist, and which has been denominated the putrid, an exact identity exists, and the greater the depression in the scale of the fibrin, the more manifest does the putridity become. While the blood is still circulating within its vessels, we can scarcely conceive of its becoming putrid; nevertheless, so great in some cases is the deficiency of fibrin, and so proportionate the consequent tendency to putridity, that even during life certain symptoms indicative of this condition become manifest, as the extreme prostration of the strength, the fœtor which belongs to all the excretions, and the vital principle having escaped, the external signs of decomposition almost immediately appear.

The characters of the blood in hemorrhages scarcely differ from those which we have pointed out as belonging to it in fevers; from the small quantity of fibrin, and the excess of red globules, we find that the clot is large, ill-formed, very soft, and never covered with the buffy coating, and that finally, in a very short time, it undergoes almost entire dissolution, the only trace of solid matter in the blood consisting of a few shreds of fibrin.

There is one disease, viz. scurvy, in which a condition of the blood, as regards its fibrin, exists analogous to that which characterises fevers, and in which also the same tendency to repeated hemorrhages and to the formation of petechiæ belongs, as is witnessed in fevers.

It is a question for consideration whether the deficiency of the fibrin referred to is the real cause of the proneness of the blood to decomposition and dissolution; and whether, if this be the case, there is not some other prior cause which leads to and regulates the extent of the diminution of the physiological standard of the fibrin.

The experiments of Majendie show that the mixture of certain alkaline substances with the blood not merely preserve it in a fluid state, but restore to it the fluid form, even after it has once coagulated. M. Majendie injected into the veins of living animals a certain quantity of a concentrated solution of the subcarbonate of soda, and found that in the dead bodies of these animals the blood was almost entirely in a fluid state, and that even during life they presented many of the symptoms which are acknowledged to denote a state of dissolution of the blood.

The alkaline condition of the blood in scurvy, in which the proneness to hemorrhage is so great, is well known.

A fluid state of the blood is said to exist in those who have died from the bite of serpents, and it is most probable that in like manner the effect of the imbibition of a poisonous miasma is to cause the blood to retain its fluidity.

The deplorable effects which sometimes ensue from a dissection-wound are most probably due to the entrance into the blood of a poisonous matter, and in fatal cases we have all the signs indicative of a dissolution of the blood.

It is likewise asserted, that any violent impression made on the nervous system, either through the influence of some strong moral emotion, or as the result of a blow, especially on the pit of the stomach, an electric shock, as of lightning, retards, or altogether prevents, the coagulation of the blood, while at the same time it destroys life. That the same effect is likewise produced, though in a manner less obvious and less sudden, by the slow and continued operation of any cause which depresses the power of the nervous influence, so as at length to effect the health prejudicially, cannot be doubted.

The proneness of children to hemorrhages, their liability to febrile disorders, and the difficulty of restraining the bleeding which flows from any breach of continuity which the skin may have suffered, especially that of a leech-bite, in infants, are well known. The state of the blood in children is not commented upon by the talented authors to whom we have had such frequent occasion to refer in their important pathological essay on the blood: it is most probable, however, that while its globular element is somewhat in excess, that in fibrin it is equally deficient.

With one other remark we will bring this short chapter on hemorrhage to a conclusion, and proceed in the next place to consider the effect produced upon the economy by the deficiency of another element of the blood. The statistical and historical details of epidemics clearly prove that those dire forms of disease, of which extensive and alarming hemorrhages were such frequent complications, have in these latter times become much more rare. This happy result is doubtless due to the advances made in the arts and sciences, and to their more extensive application in the improvement of the hygienic condition of mankind.

Decrease in the Normal Proportion of Albumen.

It is now generally known, that the majority of cases of dropsy depend upon a pathological alteration of some solid organ of the body, as the heart and the liver; most persons are also aware of the fact that other cases of dropsy occur, which do not arise from any such morbid organic condition, but have their origin, according to MM. Andral and Gavarret, in a pathological degeneration of one of the elemental constituents of the blood.

In the dropsy which attends the advanced stages of the affection known by the name of Bright's disease of the kidney, in that which supervenes upon scarlatina, in hydropsies arising from insufficient and improper diet, as well as in those which occasionally follow suddenly suppressed perspiration, it has been observed that the urine is always albuminous, and the writers just mentioned have ascertained the existence of a fact which stands in close relation with the albuminous excess in the urine in the instances enumerated, viz. that the blood is itself in these cases, on the contrary, deficient in albumen. The knowledge of these two facts, therefore, and the observation that their occurrence is so generally associated with dropsical effusion, has led MM. Andral and Gavarret to entertain the opinion that a close connection exists between the deficiency of albumen in the blood, and the forms of dropsy alluded to, and which is probably that of cause and effect.

In speaking of non-organic dropsies it has, until recently, been conceived sufficient to say that they depended as a cause upon impoverishment of the blood; but this expression we now know to be vague, inasmuch as it does not convey any exact notion of the real changes which the blood may have undergone: we have seen that the blood may be rich in its red globules or in its fibrin, and also that it may be poor in these elements in almost every proportion and degree. Let us see whether a deficiency of either of the two constituents just named predisposes to dropsies. In anæmic states, and in chlorosis especially, we have an impoverished state of the blood, and in these we know that it is the red corpuscles which are deficient; and yet daily experience shows us that dropsy in such states, and particularly in chlorosis, even in its most severe forms, is a very rare termination. In febrile disorders again, we have, for the most part, an impoverished condition of the blood, arising from the depression in the scale of the fibrin, and yet of these we do not find dropsical effusion to be by any means a frequent result.

It is not excess of water in the blood which gives rise to dropsy, for, if that were the case, then would it frequently occur in the disorder to which we have referred, chlorosis, in which a greater proportion of water than is normal exists in the blood.

The causes of impoverishment of the blood enumerated therefore do not act as exciting causes of dropsy: there remains but one other element of the blood, the albumen, for our consideration, and this we have seen to be constantly deficient in the blood in certain forms of dropsy, and we are therefore constrained to adopt the conclusion that this depreciation in the scale of the albumen is intimately associated with the occurrence of those forms.

It does not appear, according to M. Andral, that the albumen can undergo a spontaneous depreciation in the blood, similar to that of which we have seen that the red globules and the fibrin are susceptible; this, if correct, is very remarkable, and hence it would follow that whenever a deficiency of the albumen of the blood exists, invariably, at the same time, the urine would be found to be albuminous, provided always that no dropsical effusion existed, the effect of some organic malady.

In most organic dropsies the diseased organs act as exciting causes of the serous effusion by the mechanical impediment which their altered structure and enlarged size present to the circulation in the vessels, and which, therefore, relieve themselves by permitting the escape of a portion of their contents. In Bright's disease, although the kidney is affected, that organ does not concur in the formation of the dropsy, except in a manner altogether indirect, and to such an extent only as that the pathological alteration which its substance undergoes is of such a nature as to afford greater facility to the passage of the albumen through it.

The serosity effused in cases of dropsy is not identical in its constitution with the serum of the blood; it contains usually far less of the inorganic constituents which are held in solution in healthy serum, as well as a far less proportion of albumen than that which belongs to serum in its normal state. The physiological standard of the albumen in the blood is eighty in every thousand parts; in sixteen cases in which the serous effusion was analysed by M. Andral the scale was found to oscillate between 48 and 4, these two numbers representing the highest and the lowest proportions. In six cases of hydrocele, the amount of albumen was, as represented by the following figures, 59, 55; two of 51; 49, 35. It should be remarked that none of these analyses refer to cases of dropsy connected with excess of albumen in the urine. It would be interesting to ascertain the amount of the albuminous element contained in the serum effused in such cases.

MM. Andral and Gavarret state that they did not find that either the cause of the hydropsy, or its seat, excited any influence over the quantity of albumen of the effused serum; but they remarked that the amount did in some degree depend upon the condition of the constitution, and that the more robust its state the greater the proportion of the albumen: in this way the higher scale exhibited in the six cases of hydrocele may be accounted for, their occurring in persons all of whom were young and strong; and thus, also, the great depression of that scale may be explained in those whose constitutions have been weakened by repeated tappings.

Two explanations may be given of the reason why blood less rich than ordinary in albumen should give rise to serous effusion. The first is, that the abstraction of the albumen may alter the density of the serum, and thus permit more readily its escape through the walls of the vessels; the second is, that blood deprived of its albumen becomes less yielding, and so glides less easily along the walls of the capillary vessels, thus occasioning in them an obstruction to the circulation and consequent effusion of serum. Of these explanations the former is, perhaps, the more probable.

The proportion of water in all serous effusion is, of course, considerable, and is greatest in those cases in which there is least albumen. The mean proportion of water in the serum of the blood is 790 in 1000 parts; in the fluid of dropsies the highest scale hitherto observed is 986, and the lowest 930.

The fluid effused in burns and scalds, and as the result of the application of a blister, and which are always preceded by some degree of inflammation, are also rich in albumen. The very curious observation is made by M. Andral, that in cases where dropsical effusion exists in more than one situation in the same individual, that in each locality the fluid effused may exhibit a very different proportion of albumen. Thus, in a woman attacked with an organic affection of the heart, there were thirty parts of albumen in the fluid of the pericardium, while there were but four parts in the serosity of the cellular tissue of the inferior extremities.

In having thus ascertained the different modifications in quantity which the three great elements of the blood may undergo, the globules, the fibrin, and the albumen, it yet must be confessed that the pathological history of the blood is still very far from being rendered complete. It is more than probable that rigorous chemical analysis will disclose the fact that the several extractive as well as inorganic substances which exist in the blood vary greatly in amount in the numerous disorders to which the human body is liable. From the great quantity of these substances which are found in the urine, it would appear that the grand purpose fulfilled in the economy by this excretion is that of regulating their amount in the blood, and of reducing it to a standard consistent with a physiological condition of the system.

Into this branch of the pathology of the blood inquirers have as yet scarcely entered; and there can be no doubt but that investigations instituted in this direction would be attended by the development of many important facts.

Therapeutical Considerations.

The practical value to be attached to the various particulars related in the preceding pages on the pathology of the blood, is so obvious that it needs not to be illustrated at any great length.

The knowledge of the particular element of the blood which in any state of the system or disease may be affected, inasmuch as it discloses the chief cause of such condition or malady, furnishes the practitioner with an unerring principle upon which the nature and the extent of the treatment adopted should be founded. Hitherto, the chief guides in practice have been based upon experience and clinical observation; both, doubtless, of high importance; but still not in many cases sufficient to detect the cause of a malady, and therefore not in themselves equal to the determination of the exact line of treatment to be pursued, or of the extent to which that line should be followed.

We are now not merely acquainted with the bare fact, derived from experience, that in anæmic conditions of the system the different preparations of iron are useful, but we have dived deeper into the mysteries of organization, and we now know the reason why iron is necessarily so beneficial in the disorders to which such a condition of the system gives rise.

The precise objects to be held in view, in the employment of every remedial appliance in the treatment of inflammatory affections and fevers, we are now acquainted with; and by our present knowledge we can judge of the propriety and extent of usefulness of the various plans of treatment which in times past have been had recourse to, or which still continue to be applied; and we can detect the reason why one particular mode of treatment should have been more successful than another.

Bequerel and Rodier's Pathological Researches on the Blood.

MM. Bequerel and Rodier* have traversed the same ground as MM. Andral and Gavarret in reference to the blood, which they have examined both in health and disease.

These authors confirm many of the more important results obtained by antecedent observers, but question the accuracy of some of those results, and add new facts in relation to the normal and abnormal composition of the blood.

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* Gazette Médicale de Paris, 1844. Recherches sur la Composition du Sang dans l'état de Santé et dans l'état de Maladie.

The results which confirm those which had been previously obtained are the following: —

1. The augmentation of the fibrin in inflammations, the establishment of which fact is especially due to MM. Andral and Gavarret.

2. The diminution of the globules in chlorosis, in the condition denominated the anæmic, and under the influence of fasting; a fact stated by M. Lecanu, and confirmed by MM. Andral and Gavarret.

3. The diminution of the globules from hæmorrhages and anterior bleedings; a result which, signalised for the first time by MM. Prevost and Dumas, has been confirmed in the numerous analyses of MM. Andral and Gavarret.

4. The little influence of bleedings upon the scale of the fibrin.

5. The diminution of the albumen in the malady of Bright as indicated by Gregory, Rostock, Christison, Andral, and Gavarret.

Of the results which differ from, and perhaps invalidate those of antecedent observers, the principal are, —

1. That the scale $\frac{127}{1000}$ given as representing the mean of the globules in a state of health is too low, and is not the same in man and in woman.

2. That the scale representing the fibrin as $\frac{3}{1000}$ is too high.

3. That there is not alone in plethora an augmentation of the globules, as signalised by M. Lecanu, and as has been admitted by MM. Andral and Gavarret.

4. That the scale of the globules is not preserved in its normal proportion in the majority of acute affections.

5. That the depression in the scale of the fibrin in severe fevers is but little constant.

The more important of the new results are the following: —

1. That the scale 141 expresses the mean number of the globules in man in a state of health, and that of 127 represents the average in woman.

2. That the ordinary scale of the fibrin is 2·2, and the mean 3.

3. That in plethora there is an augmentation of the quantity of the mass of the blood.

4. That the influence of disease upon the composition of the blood is to occasion from the commencement a diminution in the proportion of the globules, and this diminution continuing during the progress of the malady, ends in the production of the anæmic condition of the system.

5. That there is an absolute excess of fibrin in many cases of chlorosis and of pregnancy, and that its diminution is far less constant than has been considered in fevers.

6. That the albumen of the blood diminishes under the influence of illness; that it is more considerable in inflammations; and further, that the diminution is in direct relation with the augmented amount of fibrin, which it may be presumed is formed at the expense of the albumen; that there is not only a very great diminution of albumen in the malady of Bright, but also in certain affections of the heart, accompanied by dropsy, and in certain severe forms of puerperal fever.

7. That the amount of cholesterine and of acid fats increases as we advance in age; but that this increase is not felt until from the fortieth to the fiftieth year; that it is also found in augmented quantities in the blood in constipated states of the system, and in jaundice, with retention of the bile and decoloration of the fæces.*

The Blood in the Menstrual Fluid.

The menstrual fluid contains all the elements of the blood, especially the red and white corpuscles, and it is therefore in the same manner as the blood itself susceptible of circulation. In addition to the constituents of the blood, we find the uterine discharge to be composed of vaginal mucus, mixed up with numerous epithetral scales, which it has acquired in its passage along the vagina.

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* The above remarks are abbreviated from an abstract of MM. Bequerel and Rodier's work on the blood, by MM. Millor and Reiset, contained in the "Annuaire de Chimie," for 1846.

Unlike, however, in one respect the blood itself, which in a state of health is alkaline, the menstrual fluid is acid, its acidity arising from its admixture with the vaginal secretion.

Transfusion of the Blood.

It has been stated, and the statement is most probably correct, that between the size of the blood corpuscles and that of the capillaries of the same animal, an exact relation exists, and it is by reference to this fact that the fatal effects which have so often ensued, from the transfusion of the blood of one animal into the vessels of another have been apparently so satisfactorily explained. The little vessels, it has been said, are too small to admit the larger globules of the new blood; a mechanical impediment is thus offered to the circulation of the blood in the capillaries, which stagnates in them, giving rise to constitutional disturbance, and ultimately to death. This explanation, plausible as it appears, has been shown by recent experiments to be erroneous, and that the true cause of the fatality which has so often attended the operation of transfusion, depends upon the difference which exists in the qualities of the fibrin in the blood of two different animals, or even of two distinct individuals: this is shown by the fact that the transfusion of blood deprived of its fibrin is never followed by the serious results to which reference has been made. Notwithstanding this fact, it is yet very evident that if the blood of an animal, the corpuscles of which are much larger than the human blood disc, and at the same time are of a different form and structure, such as for instance those of some birds, be introduced into the vessels of man, a very serious and probably fatal mechanical impediment would be presented to their circulation through the capillaries. Blood corpuscles of a circular form, and but little larger than those of man, might indeed make their way through the vessels in consequence of the plastic nature of the globuline which composes them.

The new globules thrown into this system by the operation of transfusion, although they would circulate for a time with the other blood globules, would doubtless all become destroyed and removed in the course of a few days, and this especially if the blood corpuscles were different from those of the animal from which the transfusion had been practised.

The Blood in an Ecchymosis.

When a part is bruised to such an extent as to occasion the rupture of the minute capillaries and vessels contained in it, blood is effused constituting an ecchymosis. The same effect sometimes takes place, not as the result of the application of external violence, but from disease, the solid tissues and that of the vessels especially giving way through debility, and permitting the escape of their contents, as occurs in malignant and putrid fever, in *Purpura Hæmorrhagica,* in scurvy, and in bed-sores.

If a portion of the effused blood be removed from the bruise and examined microscopically, the globules will be observed to be wrinkled and irregular in form, corresponding with and depending upon internal changes in the condition of the blood effused, and which are indicative of the occurrence of decomposition ; certain external appearances will be noticed, the skin will appear mottled, different hues of black, green, and yellow being intermixed and varying in intensity until the period of their total disappearance.

The phenomena of decomposition precede the disappearance of the red corpuscles which are removed from the seat of injury, and are returned to the circulation in a state of solution. Now were the opinion true that the blood corpuscles are applied directly to the formation of new tissue, a very different result to the decomposition and solution of the globules, to which we have referred, would be anticipated, and we should expect to find that the extravasated blood had given rise to an adventitious and organised product, an event to which ecchymoses never lead.

The Effects of certain remedial Agents upon the Constitution and Form of the Blood Corpuscle.

We have seen, in the remarks on the effects of re-agents, that many solutions and substances applied to the corpuscles, after their abstraction from the system, modify their form, appearance, and properties.

Thus we have seen that in water, as in any other analogous liquids of less specific gravity than the serum of the blood, that the corpuscles lose their normal form and become circular, their colouring matter passing at the same time into the fluid.

We have likewise observed that in liquids of an opposite character, and the density of which equals or exceeds that of the blood, their form is preserved and even rendered flatter than ordinary: thus their shape is well maintained or but slightly affected in the white of egg, urine, the saliva, concentrated solutions of the chlorides of sodium, and of ammonium, the carbonates of potassa and ammonia, and of sugar.

The blood corpuscles likewise preserve their form in the solutions of other substances, the density of which would not appear to be very great, but which are possessed of very strong and decided properties; thus they maintain their shape well in a solution of iodine, and become but slightly contracted in those of chloride of sodium, while, according to Henle, the primitive flattened form of corpuscles swollen by the imbibition of water may be restored to them by the application of the concentrated saline solutions.

Nitric acid produces an irregular contraction of the corpuscles. It has been remarked in like manner that a host of substances affect the colour of the corpuscles.

But it is not alone the form and colour of the blood corpuscles which are affected by the contact of re-agents; their properties also are modified by them.

Thus the corpuscles to which iodine has been added are so hardened by it that they experience little or no change of form in the addition of water.

The same is the case, according to Henle, after treatment by nitric acid.

The acetic, and one or two other acids, it is known, dissolve the corpuscles of the mammalia without residue, but leave almost unaffected the granular nucleus contained in the red blood corpuscles of the oviparous vertebrata.

The above are some of the more striking effects produced in the form, colour, and constitution of the blood corpuscles out of the system, on their treatment by reagents.

Now there is evidence to show that blood corpuscles, while they are circulating in the body, are likewise affected, although to an extent less considerable, and therefore less appreciable, by substances and solutions introduced into the system through the medium of the lungs or of the stomach.

Thus we know that the blood changes its colour in the lungs and during its circulation through the capillaries, and that these changes are dependant upon the relative amount of oxygen and of carbon contained in the corpuscles.

Again, it has been asserted by Schultz, as already mentioned, that accompanying these alterations of colour there are also changes of form, the corpuscles becoming more or less circular in carbonic acid and hydrogen gases, and flat in oxygen gas. This assertion I have myself failed to verify.

It cannot be doubted, however, but that the form of the red blood corpuscle must vary according to the variations of density experienced by the *liquor sanguinis,* and further but little hesitation can be felt in admitting that this alteration of density does really attend upon particular conditions of the system; thus, in inflammatory affections, the liquor sanguinis is assuredly more dense than it is in states in which an opposite condition of the blood exists, that in which the watery element abounds.

After very copious imbibition of water also, it can scarcely be doubted but that the density of the blood is lessened, and that the red corpuscles are modified in shape in consequence.

Thus much for colour and form; let us see if we are acquainted with any fact capable of proving that the constitution of red blood corpuscles is also influenced by the introduction into the stomach of remedial agents.

Schultz relates the fact that the corpuscles of the frog, in the mouth of which during life iodine had been placed, resisted for a longer time the action of water.* The truth of this most interesting and important observation I have myself verified.

The blood corpuscles of a frog, which was subjected to the vapour of iodine, underwent no appreciable change of form in water for nearly an hour during which they were observed, a time more than sufficient to ensure the complete change of shape and subsequent disintegration of the blood discs of a frog not similarly treated.

It may be observed that in the case related, starch failed to detect the presence of iodine, although this was set free by previously dissolving the corpuscles by means of acetic acid.

After the relation of the above facts, it is evident that remedial agents do affect in several important particulars the blood corpuscles of the living animal, and it is further probable that a considerable proportion of their remedial influence is dependant upon the nature and extent of their power in modifying the red blood disc.

The importance of a Microscopic Examination of the Blood in Criminal Cases.

In criminal cases it is sometimes a matter of the highest importance to the furtherance of the ends of justice, that the nature of certain stains, observed on the clothes of an accused person, should be clearly ascertained.

The fact usually to be determined is, whether the stains in question are those of blood or not. Now in the decision of this important matter, the microscope comes to our aid in a manner the most decisive and convincing.

If the stain be a blood stain, and if its examination be properly conducted, the microscope will lead to the detection in it of the blood corpuscles themselves both white and red.

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* Das System der Circulation. Stuttgard, 1836, p. 19.

The enquiry having been proceeded with thus far, and the stain having been proved to be one formed by blood, it sti remains for decision, whether the blood thus detected is human or not.

In the solution of this difficulty the microscope likewise affords considerable assistance, and this of a kind which can be obtained in no other way. Although by this instrument we are not able to assert positively from an examination of the blood stain itself, free from admixture with any other organic material, that the blood is really human, we yet shall have it in our power very frequently to declare the converse fact, viz., that a certain blood stain is constituted of blood which is not human, a particular on the knowledge of which the life of an accused individual might depend.

Thus if we find that the blood globules are of a circular form and destitute of nuclei, we may safely conclude that they belong to an animal of the class Mammalia, although, at the same time, we in all probability should not be able to pronounce upon the name of the mammal itself; if, on the contrary, the blood corpuscles are elliptical and provided with a granular nucleus, we may be equally certain that they do not appertain to that class, but either to the division of birds, fishes, or reptiles.*

By the size also as well as the form of the corpuscles, some idea of the animal from which the blood was derived might be formed; and if we cannot pronounce with certainty upon this, we shall at all events, and at all times, be able to go the length of affording negative evidence, and of asserting that the corpuscles do not represent the blood of certain animals which might be named, and a knowledge of which fact might prove of extreme importance.

To show the valuable nature of the evidence which it is in the power of a medical man who makes a right use of the microscope frequently to afford, in criminal inquiries, we will suppose the following case.

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* The only animals of the class Mammalia which have blood corpuscles of an elliptical form, are those of the order *Camelidæ;* they are, however, very small, and destitute of nuclei.

A person is apprehended on the suspicion of having been concerned in a murder. On his clothes are observed certain stains; upon these he is questioned; he admits that they are blood stains, and states that he had been engaged in killing a fowl, and that in this way his clothes had acquired the marks. The stains are now submitted to microscopic examination; the blood of which they are constituted is found to belong to an animal of the class Mammalia, and not to that of Aves; discredit is thus thrown upon the party suspected, fresh inquiries are instituted, fresh discoveries made, and the end of all is the conviction of the accused of the crime imputed.

But a third question presents itself, to which it is very necessary that a satisfactory reply should be made, viz., did the blood, of which the stain is constituted, flow from a living or dead body? This query we will proceed to answer.

If a vessel be opened during life, or even a few minutes after death, the blood which issues from it in a fluid state will quickly become solidified from the coagulation of the fibrin.

But if, on the other hand, a vessel be opened some hours after death, the fluid blood which escapes will not solidify because it contains no fibrin, this element of the blood having already become coagulated in the vessels of the body in which it still remains.

Now this act of the solidification of the fibrin is deemed by many to be a vital act, and to be the last manifestation of life on the part of the blood.

It would appear, however, that the coagulation of the blood should not be regarded as a vital act, seeing that blood which has been kept fluid for some time by admixture with saline salts will coagulate when largely diluted with water, and also, that blood which has been frozen previous to coagulation will undergo the process of solidification after it has been rendered fluid again by thawing.*

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* Dr. Polli has related a case in which the complete coagulation of the blood did not take place until fifteen days after its abstraction. — Gazzetta Medica di Milando, 1844.

Presuming, then, that the coagulation of the blood is not an act of vitality, the inference to be deduced from the presence of coagulated fibrin in blood stains, in which the corpuscles may be detected, is scarcely weakened thereby, since the finding of such fibrin in such a situation, and in connexion with the blood corpuscles, scarcely admits of a rational and probable explanation of its occurrence being given apart from the idea that the blood had issued from a body either living or but just dead, and in which coagulation of the fibrin in the vessels had not occurred.

The blood stains, therefore, which contain coagulated fibrin in them, it is but little doubtful must have proceeded either from a living individual, or from one but just dead; while, on the contrary, it is as little to be doubted, but that those stains which do not contain solidified fibrin, must have emanated from a body dead some hours, or from blood which had already been deprived of its fibrin.

From the disposition and form also of the blood spots, some idea can be formed as to whether the blood had sprit out of a living body or not.

A few observations may now be made, first, on the length of time after the formation of blood stains at which the corpuscles can be detected; and second, on the best mode of proceeding in the examination of those stains.

From observations which I have made, it would not appear that it is necessary that the blood stain should be recent. I am inclined to think that the period scarcely admits of limitation.

Thus in blood stains six months old, I have observed the corpuscles presenting very nearly the form and appearance proper to them when recently effused, and previous to their becoming dried up.

In the blood of the frog, six months after its abstraction from the animal, I have observed the corpuscles both red and white, and in the former, the characteristic granular nuclei with so much clearness, that it would have been an easy matter to have studied upon them the development of blood corpuscles.

The observance of one precaution, at least, is necessary for the successful exhibition of the microscopic characters of blood stains.

Thus, water should never be applied to them, nor indeed any other fluid, the density of which is less than that of the serum of the blood, for all such liquids will occasion the discharge of the colouring matter of the blood corpuscles and an alteration of their form; thus the circular but flattened corpuscles of the Mammalia will assume a globular shape, as will also the elliptical blood discs of birds, fishes, and reptiles, one of the greatest points of difference between the blood corpuscles of the former and latter classes being thereby effaced.

Blood stains, therefore, should be moistened, previous to examination, with some fluid, the density of which nearly equals that of the *liquor sanguinis;* and I have found the albumen of the egg to preserve the form of the corpuscles excellently well.

Failing, however, in detecting the blood corpuscles, a result scarcely to be anticipated, assistance may be derived from a toxicological examination of the blood.

The only tests peculiar to the blood are those which have relation to the hœmatine. This principle it would, however, be difficult to obtain from blood stains in sufficient quantity for the purposes of copious chemical analysis.

Nevertheless, corroborative evidence of the suspected character of a stain might be obtained by its general chemical analysis, and which should be treated as follows.

The stain should first be moistened with cold distilled water, as much of the matter of it should then be removed as possible, and placed in a test tube with an additional quantity of water. This being agitated, the colouring material, if the stain be a blood stain, will be dissolved by the water, imparting to it a pinkish colour, while, provided the blood flowed from the body during life, or at all events within a few minutes of decease, suspended in the liquid, will be seen shreds of fibrin.

This solution, when heated to near the boiling point, will become turbid, and deposit flakes of albumen.

The same thing will occur when it is treated with nitrate of silver or bichloride of mercury.

The addition of a strong acid or alkali turns the colouring matter of a brown tint.

These results, however, are common to other mixtures of animal substances in combination with colouring matter besides the blood, and no one of them is perfectly characteristic.

It would therefore appear, that the microscope is capable of revealing evidence much more satisfactory in reference to the nature of blood stains, than that which it is possible to derive from chemical examination.

Finally, it may be observed, that during the examination of blood stains, other substances may be detected in connexion with them, the presence of which would reveal not merely their nature, but also the seat from which the blood forming them had flowed; thus some of the various forms of epithelial cells and of hairs, may occasionally be encountered in them.

We now bring to a conclusion this long article upon the grand formative fluid of the system, the blood, and pass to the consideration of other fluids of the economy, viz., pus and mucus.

ART. III. MUCUS.

We have seen that the blood consists of two parts, the one fluid, the *liquor sanguinis*, the other solid, the globules; the same constitution belongs also to mucus as well as to some other of the animal fluids, as for example, pus and milk.

Mucous globules find their analogue in the white corpuscles of the blood, while the fluid portion of mucus resembles closely the fibrin of the blood, fibrillating or resolving itself into fibres in the same manner as the fibrin. From this fact there can be no doubt but that the transparent or fluid constituent of mucus is mainly composed of fibrin.

It is probable that the fluid portion is the only essential constituent of mucus, and that the globules are connected with it merely in an indirect and secondary manner, notwithstanding that their presence is all but constant. The correctness of this view is in some measure sustained by the fact, observed first by M. Donné, that the mucus obtained from the neck of the uterus, in young girls, is invariably free from corpuscles.

It is with the solid particles of the mucus that we shall be chiefly occupied, for they more properly enter into the domain of the microscope; the fluid element eludes to a great extent the power of this instrument, and the detection of its properties enters principally into the province of the chemist.

GENERAL CHARACTERS.

Healthy mucus, in its fluid state, is a transparent, viscid and jellylike substance, which does not readily become putrescent; in its dried condition, it assumes a dark appearance, and a horny and semi-opaque texture; in water it swells up, re-acquiring most of the properties which characterised it when recent. It sometimes exhibits an acid, and sometimes an alkaline re-action, according to the exact structure of the mucous membrane by which the mucus is itself secreted.

Mucous membranes, therefore, as might be inferred from the concluding passage of the preceding paragraph, do not all present a constitution precisely similar the one to the other; and on their differences of organization a division of them into three classes may be instituted, as has been pointed out by M. Donné.

The first class of mucous membranes comprises those which are contiguous to the outlets of the body, and which are to be regarded as extensions of the skin, participating in all its properties: thus the fluid secreted by this class of mucous membranes manifests, like that of the skin, an acid re-action, and the same epithelium which invests the latter belongs also to the former; in other respects the correspondence is likewise exhibited, the membranes under consideration manifest the same sensibility, the same freedom from hemorrhage, which characterise the skin; they in like manner ulcerate less readily, and are never furnished with the vibratile ciliæ which belong to the second class of mucous membranes, viz. the true. This first described class of membranes may be denominated *false* mucous membranes; and as an example of it the vagina may be cited.

The membranes which belong to the second class are situated more internally than the last, and have scarcely any thing in common with those of the first class: the mucus secreted by them constantly exhibits an alkaline re-action, and the epithelium which invests them is of a totally different structure, the cells which constitute it being cuneiform, and in some situations provided with numerous vibratile ciliæ: the general properties of this class of membranes are also opposed to those of the previous division: thus they are but little sensitive to the touch, are frequently the seat of hemorrhages, and ulcerate with much facility. The membranes of this class are to be considered as the *true* mucous membranes, and that which lines the trachea and bronchi may be instanced as the type of this class.

The third class is more artificial than the two preceding; the membranes which it comprises exhibit in a greater or less degree the characters of each of the divisions already described, between which they are intermediate in situation, as in structure, participating in the characters of the false or true mucous membranes more or less, according to the preponderance of either of these classes. The membranes of this division may be called *mixed*, and those of the mouth and nose may be regarded as typical.

Now, however useful for the purposes of description the above classification may be, it must still be remembered that it is, to a very considerable degree, arbitrary; the membranes which we have described as false mucous membranes belong rather to the skin than to true mucous structure, while the mixed membranes exhibit only the gradual transition from the external skin to the internal true mucous membrane: thus, strictly speaking, there is but one class of mucous membranes, and that the true. Corresponding with the differences which have been pointed out as characteristic of the three classes of mucous membranes, there are others appertaining to the mucus secreted by each of these orders of membranes, and which arise from their diversity of structure, and which serve to distinguish the mucus of the one class from that of each of the other classes.

1st. The mucus proceeding from true mucous membranes is viscous and alkaline, containing, imbedded in its substance, numerous spherical, semi-transparent, and granular corpuscles of about the $\frac{1}{2250}$ of an inch in diameter (see Plate XI. *fig.* 1.)*, having a somewhat broken outline, as well as occasionally epithelial cells more or less cuneiform, and sometimes provided with ciliæ. These corpuscles are for the most part nucleated, they are not at first soluble in water, but swell up in that fluid to two or three times their former dimensions (see Plate XI. *fig.* 3.), and, like the white globules of the blood to which they bear the closest possible resemblance, they contract somewhat under the influence of acetic acid, and are soluble in a concentrated solution of ammonia.

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* A law having reference to size, and the importance of which will be hereafter demonstrated, may here be announced. It is that the several structures, especially the corpuscular ones, entering into the composition of the animal organization, bear a near relation of size the one to the other.

2nd. The mucus secreted by false mucous membranes, or those which are analogous to the skin, although more or less thick, does not admit of being drawn out into threads, is acid, and in place of spherical globules contains numerous scales of epithelium which differ from true mucous globules in their much larger size, flattened form, and in their irregular and very frequently oval outline: these scales, like the true mucous corpuscles, are nucleated, and the nuclei comport themselves with chemical reagents, in the same manner as the globules of mucus.

Example: — the mucus of the vagina. (See Plate XII. *fig.* 1.)

3rd. The mucus proceeding from the mixed or transition membranes is sometimes acid, sometimes alkaline, at others neutral, and contains a mixture of true mucus corpuscles and epithelial scales, the relative proportion of each of which varies according to the exact structure of the membrane by which it is furnished. (See Plate XII. *fig.* 2.)

These divisions of the mucus into three different kinds, although to some extent artificial as already observed, are yet not without their practical utility.

The microscopical and chemical characters of mucus likewise vary much, not merely according to the general organization of the membrane by which it is secreted, but also in accordance with the condition of the membrane itself, with the degree of irritation or inflammation to which it is subject, and with the precise nature of the disorder by which it is affected; thus, sometimes, the mucus secreted by the lining membrane of the nose is thin and watery, the fluid element being in excess, and at others it is thick and opaque, its solid globular constituents superabounding. Its colour also as well as its consistence exhibits various modifications in pathological states, being sometimes white, greenish or yellow.

The description of the different forms of epithelial cells alluded to, and which are occasionally encountered in the mucus mixed up with true mucous corpuscles, belongs not to the fluids, and will be given in detail under the head of Epithelium, in that division of the work which is devoted to the consideration of the solids of the human body; the structure, form, size, properties and nature of the true mucous corpuscles may here be described with advantage.

Mucous Corpuscles.

Structure.—The mucous corpuscles, which are colourless and mostly of a circular form, are each constituted of a nucleus, an envelope, an intervening fluid substance, and numerous granules, which are diffused generally throughout the entire of the corpuscles, being contained within the cavity of the nucleus, in the space between this and the outer envelope, and, lastly, in the substance of the envelope itself; this arrangement imparting a granular texture to the entire corpuscle. (See Plate XI.)

The nucleus, like the corpuscle itself, is a circular body of about one-third, or one-fourth its size: it sometimes occupies a central, but very frequently an eccentric position in the mucous globule: it is not at all times visible, although very generally so, without the addition of re-agents, the best being water and acetic acid.

The addition of water to mucous corpuscles discloses, in the majority of them, but a single nucleus (see Plate XI. *fig.* 3.); in some, however, two and even three or four nucleoli appear, these resulting from the division of the substance of the single primary nucleus.

The effect of a weak solution of acetic acid is the same as that of water, except that an additional number of corpuscles are seen after its application to possess the divided nucleus, whilst in others the single nucleus is observed to be oval, and occasionally contracted in the centre, this form being the transition one from the single to the double nucleus. (See Plate XI. *fig.* 4.)

If undiluted acetic acid be used, then all the corpuscles will present a compound nucleus, consisting of two, three, four, or five nucleoli, the usual number being two or three; the investing membrane at the same time under its influence loses its granular aspect, and appears transparent and smooth. (See Plate XI. *fig.* 5.)

The formation of these nucleoli may be thus explained:—The effect of acetic acid is to contract the entire corpuscle; on the nucleus, however, it would appear to operate with such force as to occasion a complete division of its substance.

The divided nucleus has been observed by many observers in the pus globule, but its occurrence in the mucous corpuscle has not been generally noticed; this division of the nucleus has been considered to constitute an exception to the law of the development of a cell around a single nucleus; whether it ought to be so regarded is doubtful, seeing that these multiplied nuclei are usually the result of the operation of a powerful re-agent, and are but rarely visible, unless as the consequence of the application of some re-agent.

Mr. Wharton Jones has endeavoured to meet this conceived exception, by supposing that the nucleoli are all enclosed within the membrane of the nucleus. I have myself, however, failed to detect the existence of any envelope surrounding the nucleoli.

Form.—The form of the mucous corpuscle, although usually spherical, is subject to considerable variety, this depending frequently upon the density of the fluid in which it is immersed, but occasionally also upon the amount of pressure to which it may be subjected.

Thus, in fluid which is very dense, the operation of exostosis is set up between the corpuscle and the fluid medium which surrounds it, whereby a portion of its contents passes into that medium, as a consequence of which its investing membrane collapses and exhibits a variety of forms. (See Plate XI. *fig.* 2.)

Corpuscles thus affected nevertheless retain the power of re-assuming the form which properly belongs to them when they are immersed in water or any other liquid, the density of which is less than that of the fluid contained within the cavity of the corpuscle itself. (See Plate XI. *fig.* 3.)

The form of the mucous corpuscle is also subject to alteration from another cause, *viz.* pressure. Thus it is often seen to be of an oval form in thick and tenacious mucus; this shape results from the pressure exercised upon the corpuscles by the almost invisible fibres into which the fluid part of mucus resolves itself, and which often become drawn out in the adjustment of the mucus on the port-object of the microscope. (See Plate XII. *fig.* 3.)

The oval shape thus impressed upon it is permanent, because the pressure of the fibres of the solid mucus ceases not to act: if the pressure however be direct, and the corpuscle be immersed in a thinnish fluid, it will resume the spherical form, the compressing force being removed, owing to the elasticity with which it is endowed.

Size.—The size of the corpuscle is also liable to much variation, this resulting mainly from the condition of the fluid as to density, in which it is immersed.

Thus, in water, or any other fluid, the density of which is less considerable than that of its contents, the corpuscle imbibes by endosmosis the liquid by which it is surrounded, to such an extent as to cause it to exceed by two or three times its former dimensions. (See Plate XI. *fig.* 3.)

By reference then to the two particulars referred to, *viz.* the density of the medium in which it dwells, and pressure we are enabled to explain all the varieties of form and size which the mucous corpuscle presents.

Properties.—From the preceding remarks on the structure, form, and size of the mucous corpuscle, we perceive that in all these particulars, it accords closely with the white corpuscles of the blood; we shall now proceed to show that there are other points of resemblance between the two organisms.

Thus re-agents affect mucous corpuscles in a manner precisely similar to that in which they act upon the white globules of the blood; water causes them to increase in size, acetic acid contracts them somewhat and renders the nucleus and the molecules more distinct. Between mucous corpuscles and the white globules of the blood there is, then, a *structural* identity; but let us see if there be not also a *functional* correspondence.

NATURE OF MUCOUS CORPUSCLES.

Mr. Addison * conceives "that mucous and pus globules are altered colourless blood-corpuscles," from which opinion it is evident that gentleman believes that the white corpuscles of the blood pass normally through the walls of the blood-vessels, although he does not appear satisfactorily to have witnessed the exact manner of their escape.

The perfect identity of organization existing between the colourless corpuscles of the blood and mucous and pus globules, would predispose the mind to adopt that view as sufficient and correct, which endeavoured to prove that they all had a common origin in the blood.

It must nevertheless be remembered that the notion of the identity in origin of the mucous and pus globule with the colourless blood-corpuscle, rests upon the single supposition that the latter does really escape from the blood-vessels, in which originally it is formed.

It seems to me, however, that this statement, to which I was myself at one time disposed to attach some importance, may be fairly challenged, seeing that the direct passage of the white corpuscles of the blood appears never to have been clearly witnessed.

Moreover, the idea of any such escape of the white corpuscles is opposed to that view which reasoning alone would lead one to entertain; thus, if the colourless corpuscles of the blood possessed the power of escape from their vessels, no good reason could be advanced why the red globules should not also pass through them.

If the capillary vessels terminated by open mouths, which we know that they do not in their normal state, then indeed it would be highly probable that mucous and pus corpuscles were the white corpuscles of the blood, escaped from the vessels.

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* Transactions of Prov. Med. and Surg. Association, vol. xii. p. 255.

I am disposed, then, to question the accuracy of the view entertained by Mr. Addison, and to believe that the globules of mucus are formed externally to the blood-vessels; the mucous glands or crypts which are scattered so abundantly over the surface of all mucous membranes, having a considerable share in their formation.

That the mucus-bearing glands are intimately connected with the development of mucous corpuscles seems proved by the fact, that the fluid expressed from them is filled with corpuscles of a smaller size than ordinary mucous globules, and destitute of any admixture with epithelial scales; these corpuscles certainly could not have found entrance into the cavities of the glands from without. (See Plate XI. *fig.* 6.)

The opinion that the mucous corpuscles are formed externally to the blood-vessels, is also supported by the observations of M. Vogel, who remarked that the plastic exudation which covers the surface of a recent wound contains, at first, only minute granules: these after a time become associated in twos and threes, and surrounded by a delicate envelope; finally, fully formed mucous or pus corpuscles appear in the liquid.

Henle believes that the white corpuscles of the blood, of lymph and of chyle, as well as those of mucus and pus, are elementary cells; and he says of the pus corpuscles that they are nothing else than elementary cells in process of being transformed into those of the tissue which the organism regenerates in the injured part; and of the white globules of the blood he writes, they are, without the least doubt, transformed into blood corpuscles.

This opinion of Henle accords closely with that of Addison, who believes, as already stated, that out of the white globules of the blood, all other corpuscles met with in the body are formed, the former escaping from the blood-vessels.

I also regard the white corpuscles of the blood as elementary or tissue cells, although at the same time the views entertained by myself respecting them differ from those both of Henle and Addison; thus I do not consider, with the former, that the colourless corpuscles are transformed into red blood discs, nor with the latter, that every other cell met with in the animal organism, proceeds from the white corpuscles of the blood.

The white corpuscles of lymph, chyle, and blood I conceive to be transformed into the epithelial cells, which constitute the epithelium with which the internal surface of the vessels of the entire vascular system is provided.

The corpuscles of mucus I conceive to have an origin distinct from the colourless globules of the blood; but in like manner I regard them as elementary or tissue cells, believing that they are finally developed into the different forms of epithelium encountered upon the surface of mucous membranes.

The corpuscles of pus are also elementary cells, and mostly altered mucous corpuscles.

The view just expressed as to the nature of the white corpuscles of the blood, is one which has but recently impressed itself upon my mind. It is not opposed, however, to the opinion previously put forth of the connection existing between these corpuscles and nutrition, seeing that, whether in their early stage of development as colourless blood globules, or in the more mature condition of their growth as epithelial scales, they are doubtless to be regarded as secreting organs, and as effecting some important change in the constitution of the *liquor sanguinis.*

The only respect in which the opinion that the colourless globules of the blood are converted into the scales which constitute the lining epithelium of the vessels, is at variance with a previously expressed view, is in relation to the escape of those globules as an usual occurrence; an opinion of Mr. Addison, in which I was formerly disposed to concur, but which I am now inclined to reject.

A final reason which may be stated for disbelief in the identity as regards the origin of the colourless corpuscles of the blood and mucous globules, is the difficulty, not to say impossibility, of explaining how these colourless corpuscles, having precisely the same form and origin in the commencement, should, in one situation, be developed into a shape and a structure so totally dissimilar to that which the same corpuscles in another position exhibit, the varieties of form and structure of epithelial scales into which the white corpuscles are supposed to be developed being so considerable.

Mucous globules, then, are to be regarded as young epithelial scales, as are also the colourless globules of the blood; they both have a like structure and a corresponding function to perform, but they have a different origin, thus the mucous globules are developed externally to the lymphatics and blood vessels, while the colourless blood corpuscles are formed within those vessels.

The further consideration of the ulterior development of mucous corpuscles, or young epithelial cells, will come more appropriately under the head of Epithelium.

Blood corpuscles not unfrequently occur mixed up with mucous globules, as in the mucus thrown off during parturition (see Plate XII. *fig.* 1.), and as in the rust-coloured expectoration of Pneumonia.

THE MUCUS OF DIFFERENT ORGANS.

After the threefold division of mucus which we have given, founded upon the structure of the membranes by which it is secreted, and after the description which has been entered upon of the peculiarities appertaining to the mucus of each of those divisions, it will be unnecessary to enlarge at any length upon the characters presented by the mucus secreted by the membrane which belongs to each particular organ or part; it will be sufficient just to enumerate the names of the membranes by which each description of mucus is furnished, and to point out any peculiarities which the mucous secretion of any particular organ may present: this having been done, and the distinctive characters of the three forms of mucus having been recalled to mind, we shall then be in a position to assign to the mucus of each locality its principal characteristics.

Thus the mucus furnished by the nasal and bronchitic mucous membranes, and which may be called nasal and bronchitic mucus, as also that of the digestive tube, from the pyloric orifice of the stomach unto near the termination of the rectum (the cæcum alone excepted), of the urethra, prostatic gland, vesiculæ seminales and the uterus, belongs to the first division of mucus, viz. that which is secreted by the true mucous membranes. (See Plate XII. *fig.* 3.)

The mucus of the vagina presents the best example of the mucus of the second class, which is secreted by the false mucous membranes. (See Plate XII. *fig.* 1.)

Lastly. The mucus of the mouth, rectum and bladder, appertain to the third description of mucus, and which is supplied by the mixed mucous membranes. (See Plate XII. *fig.* 2.)

Vaginal and Uterine Leucorrhea.

One practical result arising from the discrimination of mucus into different kinds may here be alluded to; thus by means of the difference in the microscopic characters of the mucus secreted by the uterus and that furnished by the vagina, it is in our power to decide in cases of leucorrheal discharge, whether the affection has its seat in the mucous membrane of the uterus or in that of the vagina. The mucous membrane of the uterus, as we have seen, belongs to the class of true mucous membranes, that of the vagina, on the contrary, to the false mucous membranes; now if the leucorrhea be uterine, the discharge will present the globules characteristic of the secretion produced by the class of true mucous membranes; if, on the other hand, it be vaginal, the mucus will contain the epithelial scales which belong to the mucus of false mucous membranes; moreover, the former mucus will be alkaline, and the latter acid.

Effect of Acid Mucus on the Teeth.

The degree of acidity presented by the mucus of the mouth varies considerably, according to the relative proportions of mucus and saliva which exist in the mouth at the time at which the re-action of its secretions is tested, and which proportion differs both at different times of the day, and in different states of the system, and especially of the stomach. The mucus of the mouth we know to exhibit in states of health an acid re-action, while the saliva, on the contrary, manifests an alkaline constitution; the tendency of these two fluids is therefore to produce a neutral secretion, and this explanation will account for the opposite results which have been obtained by different observers. The best time to ascertain the chemical re-action of the buccal mucus is in the morning when there is an accumulation of it on the tongue and around the gums; and the best method of determining the acid or alkaline qualities of the saliva, is first to scrape the tongue well, and as far as possible free the mouth of mucus, and then proceed to test the saliva as it issues from the orifices of its ducts.

A highly acid condition of the mucus of the mouth is assuredly productive of injurious effects upon the teeth. Although this state of the buccal mucus cannot be regarded as giving rise to the peculiar caries to which the teeth are so remarkably liable; nevertheless it cannot be doubted that it predisposes the teeth to this affection, and that it hastens greatly the progress of the decay when once this has commenced. To correct the condition of the stomach if it be faulty, the internal administration of alkalies should be had recourse to; and to remedy the local acidity, tooth powders, composed principally of some alkaline carbonate, should be employed.

The Vaginal Tricho-Monas.

M. Donné has discovered in the vaginal mucus of women labouring under discharges, either specific or otherwise, a new species of human parasite belonging to the order of Infusoriæ. This animalcule, owing to its resemblance to the spherical mucous globules with which it is constantly associated, is with difficulty discoverable by those who are not practically familiar with its appearance, and the mode of detecting it. Thus it presents nearly the same size, form, granular structure, and colour as the mucous corpuscles alluded to; it is to be distingushed from these, however, by the independent locomotive power which it possesses, the movements which it performs being produced principally by means of a long lash or cilium with which its anterior extremity is furnished, and the presence of which causes the animal to lose somewhat its circular contour, and assume a form approaching the oval; in addition to this long cilium, three or four other shorter cilia exist, which surround the mouth, and which can only be satisfactorily detected when the motions of the animalcule become somewhat retarded. (See Plate XII. *fig.* 6.) In order that it may be seen alive and in active movement, it is necessary that the mucus containing it should be submitted to examination as soon as possible after its removal from the vagina; the animal once dead, it is then almost impossible to distinguish it from a mucous corpuscle.

M. Donné, on first discovering this parasite, was for some time in doubt as to whether its occurrence was to be regarded as having any connection with the specific disorders of which the vagina is sometimes the seat, and he has at length arrived at the conclusion that no such relation as that suspected exists, and that any inflammation, specific or otherwise, sufficiently active to give rise to the secretion of puriform matter, may be accompanied by the *tricho-monas* which has been described.

In addition to the positive characters which have been indicated, denoting the presence of this animalcule, there is another altogether indirect which serves to signalise its existence in the vaginal mucus, and this is the presence in it of air-bubbles which are not encountered in healthy mucus.

Vaginal Vibrios.

The tricho-monas is not the only animalcule which lives in the mucus of the vagina; there are frequently met with in it minute *vibrios*, which, to be satisfactorily seen, require to be viewed with a magnifying power of not less than the $\frac{1}{500}$ of an inch.

In the same manner as the tricho-monas, they always occur in connection with pus globules; they are not, however, any more than the tricho-monas, to be regarded as indicating the existence of specific or venereal affections, although they are not unfrequently met with in the secretion of chancres of an undoubtedly specific character.

ART. IV. PUS.

GENERAL CHARACTERS.

HEALTHY, phlegmonous, or laudable pus, is a fluid of the colour and consistence of cream, readily miscible with water, in which after a time it sinks; it does not admit of being drawn out into threads, and exhibits usually an alkaline, though sometimes an acid, re-action.

Like mucus, which it resembles so closely, pus is made up of two constituents, the one fluid, the other solid; these, if allowed to stand at rest for a time, will undergo a spontaneous separation from each other, the corpuscles subsiding to the bottom, and the fluid or serum floating upon the top; this also will be frequently observed to be covered with a delicate film composed of oil globules. The fluid portion of pus, as of mucus, is probably the only essential, as it certainly is its only distinctive constituent; but while the latter is sometimes free from globules, the former is never without a greater or less amount of corpuscles, on the presence and numbers of which its opacity, its colour, and its consistence mainly depend.

The general characters of pus, however, undergo many changes in disease; thus its consistence, colour, smell, and all other sensible qualities vary greatly in pathological conditions.

IDENTITY OF THE PUS AND MUCOUS CORPUSCLE.

The globules of pus resemble in all essential particulars those of true mucus, the characters of which have been already described; thus, they present the same form, the same constitution, and they comport themselves in a manner almost identical with chemical re-agents. (See Plate XI. *fig.* 1., and Plate XIII. *fig.* 1.)

In one respect only can a difference in the effect of reagents on the pus and mucous corpuscles be detected; this difference is, however, one of degree, and not of kind; thus the mucous corpuscle is less readily acted upon by the acids than the pus globule; in the former a solution of acetic acid, not too concentrated, will often disclose but a single, although large, nucleus; while the same solution applied to the latter, will render apparent seldom less than three or four nucleoli. (See Plate XIII. *fig.* 2.) This is, however, by no means a constant result, and the effect of the application of strong acetic acid to the mucous globule is almost invariably to render apparent three or four nucleoli; so that from the circumstance of the number of nuclei disclosed by acetic acid, no opinion can be formed as to the nature of the corpuscle, whether it be a mucous or a pus corpuscle. Of the accuracy of this view, notwithstanding that a contrary opinion is held by many observers, not a doubt can be entertained.

It is not in every example of pus that we find the well formed and spherical corpuscles, which characterise healthy and normal pus. In the pus which has been long secreted, as in that of old abscesses, we find but few corpuscles, the majority being broken up and reduced to their elementary particles. (See Plate XIII. *fig.* 5.)

The best examples of pus corpuscles are seen in pus which has been but recently secreted, as in that just formed on some healthy granulating surface. (See Plate XIII. *fig.* 1.)

When, therefore, pus and mucous globules are spoken of, it is not to be understood that these terms indicate two distinct structures, but merely the occurrence of the same solid element in two fluids, which, although usually presenting some points of difference, are in all probability not essentially distinct.

THE NATURE, ORIGIN, AND FORMATION OF PUS CORPUSCLES.

In having indicated the nature of mucous globules, we have also, to a very great extent, pointed out that of pus corpuscles, seeing that the corpuscles of both have an organisation precisely similar.

One of the earliest opinions formed in reference to the nature of pus was, that it was constituted of blood deprived of its colouring matter, a view which was entertained even before the discovery of the blood corpuscles themselves.

Subsequently to the period of the detection of the red corpuscles in the blood, many observers have conceived that pus consists of these corpuscles altered merely in colour.

A third opinion in reference to the formation of pus and mucous globules is that of Vogel, who maintained that they arose out of a transformation of the epithelium, the nuclei of which constituted the corpuscles. This view, although not without ingenuity, has but little even of probability to recommend it, and it will be perceived that it is the very reverse opinion to that which is maintained in these pages, and which is that the epithelium is itself derived from mucous and pus globules.

We have already, under the head of Mucus, adverted to the opinion of Addison, that mucous and pus globules are altered colourless blood corpuscles, an opinion which we have also endeavoured to refute, principally by reference to the impossibility, save from lesion, of the escape of the white corpuscles from their containing vessels.

Reference has also been made to the view entertained by Henle respecting the nature of pus corpuscles, who says of them that they are nothing else than elementary cells in process of being transformed into those of the tissue, which the organism regenerates in the injured part.

I also agree with Henle in considering pus corpuscles to be elementary cells, but I differ from him in not regarding them as representing the cells of the tissue in which the pus is formed.

Pus corpuscles I conceive to be identical with mucous corpuscles, and these again are to be regarded as representing an early stage in the development of epithelial scales.

Further, it is here supposed that the formation of pus is to be viewed in the light of a salutary process, and as indicating the effort on the part of the organism, where suppuration occurs as the result of lesion of any kind, to repair the mischief sustained, and which it does by the elaboration of pus corpuscles capable of being transformed into a protecting epithelium.

In support of this view reference may be made to the fact that it is by no means uncommon to encounter epithelial scales mixed up with the ordinary pus corpuscles contained within the cavity of an abscess, or covering the surface of an old ulcer.

But it may be asked how happens it then that all pus corpuscles do not become converted into epithelial scales, and that so many of them are discharged or thrown off from the system without attaining to the higher degree of development of which they are stated to be susceptible.

This arrest of development doubtless arises from the rapidity with which the pus corpuscles are formed, and which is indicative of the strength of the *Vis medicatrix naturæ*, the result of which is that the earlier formed corpuscles become displaced by the more recently developed ones, and are thus removed without the sphere of growth, in consequence of which they perish.

Having thus considered the nature of pus corpuscles, we will next endeavour to form some opinion in reference to their origin and mode of formation; in these respects also an essential correspondence doubtless exists between pus and mucous globules.

Mandl attributes to the pus globule the same mode of formation which he has described as belonging to the white corpuscles of the blood, that is, that they are formed external to the vessels by the aggregation of molecules precipitated from the fibrin, and hence Mandl terms both the white and pus corpuscles "fibrinous globules."

This view of the formation of pus corpuscles is supported also by the observations of Vogel (already cited) made upon abraded surfaces.

Mandl, therefore, is most probably correct in his opinion as to the mode of formation of pus corpuscles, viz. by precipitation, but it is at the same time almost certain that they are not constituted of fibrin, as supposed by that micographer: this may be inferred from the different manner in which acetic acid acts upon fibrin and pus corpuscles; thus the former swells up and is rendered soft and friable by its application, while the latter under its influence become smaller, and their contained molecules more distinct.

Donné dissents from Mandl's view altogether. At page 191. of the Cours de Microscopie, M. Donné expresses himself as follows: — "Thus I do not admit that the globules of pus are formed at the expense of the fibrin of the blood; that they ought to be considered as a sort of precipitate of the fibrinous part of the fluid blood; and in spite of their analogy of structure and composition with the white globules of the blood, I nevertheless do not admit that they have any thing in common in their origin and in their intimate nature with these last. I regard the globules of pus as a product of special secretion direct from the pus forming membrane."

There appears to me to be much of error in the preceding observations: there is doubtless very much in common between the white corpuscles of the blood and pus globules, viz. a common mode of formation and a common function to perform.

At the same time it must be admitted, with Donné, that the surface or membrane, from which the pus proceeds, is also intimately associated with the development of the pus corpuscles.

DISTINCTIVE CHARACTERS OF MUCUS AND PUS.

We have now to ask ourselves the question, which doubtless many have applied to themselves before, viz. what are the distinctive characters between mucus and pus revealed to us by the microscope, and the satisfactory recognition of which has been deemed to be of so much importance?

To this inquiry no sufficient answer has as yet been returned: this difficulty the microscope has failed to solve; and this, in all probability, for the very adequate reason, that between the fluids in which a distinction has been sought no microscopic difference exists. The inquiry has been made on the false assumption that mucus and pus are really essentially distinct; and its importance has been magnified by the idea that it would impart, as indeed it undoubtedly would do if real, increased assistance in the diagnosis of disease.

Since, however, the establishment of the fact that pus may be formed independently of any appreciable structural lesion, much of the interest which was supposed to attach to this inquiry has been lost, and that which still appertains to it has been further lessened by the demonstration at which we have arrived, by means of the microscope, of the perfect identity of pus and mucous corpuscles.

Now the manifestation of this identity by the microscope is not less a triumph of that instrument than if it had really proved that the notion of physiologists was actually founded on fact, and that there does really exist a tangible difference in the microscopic characters of the two fluids.

Notwithstanding the absence of any positive known microscopic character, whereby at all times, and in all conditions, pus may be discriminated from mucus, this want of knowledge, arising from the very sufficient fact to which allusion has already been made, viz. that no such character really exists, the two fluids under discussion may frequently be distinguished, at a glance, by certain outward and physical properties and appearances, and this is especially the case when they occur without admixture with each other.

These differences in the outward character of the two fluids are not always, however, equal to their discrimination, and which arises from the fact, that they are all of them subject to the greatest possible variation, so that there is not one which can be regarded as truly distinctive. Thus in morbid conditions, the one fluid will pass by insensible degrees into the other, or they will both be mingled together in such proportions as to set at defiance all physical means employed to distinguish them.

But it may be said that the chymist can at all times distinguish pus from mucus: there can be no doubt but that, when all other means have failed, he can occasionally arrive at a tolerably accurate conclusion, but it is conceived that his powers in this respect are also limited.

Now the physical and chemical difficulties encountered in the endeavour to discriminate pus from mucus arise, in all probability, from the same cause which rendered it microscopically impossible so to do, viz. that no constant or essential difference does really belong to these fluids, whereby at all times they may be characterised.

Normal mucus and pus may be contrasted as follows: — Mucus is a thick, tenacious, and transparent substance, easily admitting of being drawn out into threads, not readily miscible with water, in which it floats, not so much from its less specific gravity as from the circumstance of its great tenacity, allowing it to retain in its substance numerous air globules, which thus render it specifically lighter than the water: it exhibits sometimes an acid, and sometimes an alkaline reaction, according to the nature of the surface from which it proceeds; and it contains imbedded in its substance solid particles of two forms, globules and scales: the former are present in alkaline mucus, the latter in that which manifests an acid reaction.

Pus, on the contrary, is a thick, opaque, somewhat oily substance, which does not admit of being drawn out into threads, is readily miscible with water, in which it sinks; its chemical reaction varies, being sometimes alkaline, at others acid: the solid particles which it contains are mostly of one kind, globules: these are always very abundant, and float freely in the fluid portion of the pus, while in that of mucus they are unable to do so on account of its tenacity.

Healthy mucus and pus, when thus contrasted, may frequently be distinguished from each other, but it is in unhealthy conditions of these two fluids, and especially when they occur mixed together in variable proportions, that the difficulty of discrimination is felt, and that the want of a certain and positive character, whereby the diagnosis may be always established, is experienced.

This mixture of mucus and pus may actually exist, or it may not, in cases of suspected phthisis, in which sputa are present. Now it is in cases of this description that we recognise the importance of the discrimination of these substances, and it is precisely in these and similar instances that the microscope utterly fails us, for the want of an ascertained and tangible difference in the two fluids submitted to the test of its powers.

Even the most marked physical qualities of pus, such as its opacity and tenuity, may all be effaced by the employment of certain reagents, and converted into those which are characteristic of mucus, thus pus, by the addition to it of *liquor potassæ* or of *ammonia*, is rendered transparent, and is transformed into a thick and tenacious substance, resembling mucus closely. This singular fact has been noticed by both Addison and Donné, and on it the former clever observer has built a theory remarkable for its ingenuity, but which is here, nevertheless, deemed to be incorrect.

The change of pus from an opaque substance to a transparent one doubtless results from the solution of the pus corpuscles, and to the presence of which the colour and opacity of pus is due; of the increased density and tenacity of the pus thus treated it is less easy to afford a satisfactory explanation.

Addison thus accounts for it: the mucus and pus globules, he says, contain filaments embedded in a fluid; these the *liquor potassæ* sets free by dissolving the envelopes of the corpuscles, and it is upon these filaments that the tenacity of mucus, and of pus so acted upon, depends. Mr. Addison, however, carries his reasoning upon the fact of the conversion of pus into a fibrillating substance similar to mucus still further. The white corpuscles of the blood, he states, also contain fibres, and that these corpuscles, immediately on their abstraction from the system, burst, giving issue to the contained filaments.

These filaments, he conceives, to constitute the fibrin of the blood, which he declares does not exist in that fluid as fibrin, but is only liberated from the corpuscles after the abstraction of the blood from the system.

The entire of this theory is here conceived to be erroneous, and this for the following reasons : —

1. The existence of such filaments in the white corpuscles has not been proved.

2. The bursting of these corpuscles referred to by Mr. Addison, is an occurrence which is rarely, if ever, seen to take place while they remain embedded in the *liquor sanguinis.*

3. The actual consolidation of the fluid fibrin may be witnessed to occur on the field by the microscope in a drop of blood, and wholly independent of any rupture of the white corpuscles, which remain without appreciable alteration.

There is some consolation, however, in knowing that this inquiry is not of so much importance as it would appear; for even were we able to make the distinction which has been the subject of so many anxious thoughts, and decide that pus did exist in the sputa, yet this fact, viewed separately, would not prove that disease of the lungs did really exist, since it is ascertained that pus may be formed without any structural lesion; and, further, if lesion were really present, it would not necessarily follow that this had its seat in the cells of the lungs, for it might be situated either in the bronchi or larynx. Thus even in this supposed case the diagnosis would be subject to considerable uncertainty.

Various opinions have been expressed by different observers in favour of the possibility of distinguishing pus from mucus. To some of these we will now refer.

There is always met with in pus, in greater or less quantity, globules of oil: the presence of these was conceived by Gueterboch to afford a sign, absolutely distinctive, between pus and mucus; that they are not so, however, is proved by the fact that similar globules are occasionally encountered in normal mucus.

Weber conceived the idea that the fluids might be distinguished by the size of the globules contained in them, the pus globule being twice as large as that of mucus: this character is likewise too uncertain, and too variable for the purposes of discrimination.

Lastly, Gruithuisen indicated, in solutions of pus and mucus in water, certain animalculæ; those generated in the former being different from those formed in the latter solution. By means of these he asserted that pus might always be known from mucus; but the infusoria described by him are not confined to the fluids in question, but are such as are formed almost indifferently in any solution of animal matter. It would appear, then, that up to the present time no satisfactory and direct means of distinguishing pus from mucus have been detected, and this for the reason assigned, that the two fluids are essentially identical.

DISTINCTIONS BETWEEN CERTAIN FORMS OF MUCUS AND PUS.

Although it is impossible to discriminate between *true* mucus and pus by means of the microscope in a positive manner, we are yet enabled to distinguish with that instrument *false* mucus from pus, because in this mucus the corpuscles exist in their fully developed form of *tessilate epithelium;* now this power of discrimination is not without importance, as will be perceived immediately.

Many persons on arising in the morning are in the habit of expectorating more or less of a substance bearing much resemblance to pus. This habitual occurrence is not unfrequently a source of much uneasiness, not merely to the person the subject of it, but also to his medical adviser whom he is led to consult upon it.

Now, in such cases as these it is often in our power to dispel the anxiety of our patient and our own at the same time; for the solid constituents of such sputa are frequently found to consist almost entirely of epithelial cells, in which case we may safely pronounce that they are not purulent; if, on the contrary, the sputa contain only globules, the evidence which this fact would furnish, although apparently, and indeed most probably, unfavourable, would still be but of a doubtful nature.

Again, the microscope will frequently determine the nature of a suspected fluid, by indicating in it the existence of shreds of cellular tissue, muscular fibrillæ, and a variety of other organisms which enter into the formation of the human body; and by the presence of one or more of which, not merely the *nature* of the puriform matter may be ascertained, but also the *locality* from which the pus had itself proceeded.

DETECTION OF PUS IN THE BLOOD.

From what has been said in reference to the structural identity of the white corpuscle of the blood with that of mucus and pus, we are prepared for the announcement that no known characters exist whereby the presence of pus in the blood may be established by the microscopic examination of that fluid.

That the elements of pus in some cases are really present in the blood, circulating with it, scarcely admits of a single doubt, since it is not unfrequently met with in situations, such as on the lining membranes of the vessels, where it is utterly impossible for it to remain without some portion of it becoming commingled with the blood.

The same fact is also proved by the spontaneous absorption of large collections of matter, an occurrence which is not unfrequently witnessed, and which is only to be accounted for on the assumption that the elements of pus are again absorbed into the blood from which originally they were derived.

There can scarcely be a question, then, that pus is occasionally contained in the living blood, although we possess only indirect means of establishing this fact; and according to the views here entertained, it may be present in the blood in two ways: thus, as we have seen, it may be formed in the blood-vessels themselves, or it may be formed without those vessels, and again reabsorbed into the blood from which in every case it almost immediately proceeds.

But pus, as we know, is composed of two elements, the one fluid, the other solid, the globules. Now we must not expect to see pus circulating in the blood as pus, although that liquid may contain all the elements of pus: the fluid portion of course, as soon as it enters the circulation, is dissipated, the solid alone remaining, and this does not constitute pus, but is only one element in the constitution of that fluid.

In certain states of disease the presence in the vessels of an unusual number of white corpuscles has been observed; now it is but little probable, that these are derived from the reabsorption of pus, which had been previously formed without those vessels; it is more natural, and more consonant with known facts, to suppose, that this accumulation is to be regarded as an indication that the disposition to the formation of pus, on the part of the blood and of the system, exists to an unusual extent, and that such a condition of the vital fluid always precedes sudden and extensive purulent collections.

Except in the case of the formation of pus in the blood-vessels themselves, it is scarcely possible to suppose that the pus corpuscles are taken bodily into the circulation again; but it would rather appear, from the condition of pus in most abscesses, that the corpuscles become disintegrated and reduced to their elementary particles, and that thus they enter the circulation again in a fluid state.

The artificial admixture of pus with the blood immediately after its escape from a vein, and before its coagulation has commenced, is productive of somewhat singular results. The clot formed in blood, which has been mixed with one quarter part of its own quantity of pus, is soft, diffluent, and dark coloured, sometimes almost livid, and the red corpuscles are found to be wrinkled and deformed, part of their colouring matter having escaped from them and passed into the serum.

These changes ensue in from twenty-four to forty-eight hours, and possibly result from the state of decomposition in which the pus itself might have been when introduced into the blood, and which condition it communicated to the mass of the blood itself.

FALSE PUS.

There are many substances and fluids having resemblance to pus which are not really purulent; thus, softened clots of fibrin, which are so frequently encountered, especially in phlebitis, bear the closest possible similitude to true pus in general appearance, and yet in their intimate structure they are totally dissimilar, as may be clearly determined by means of the microscope.

If a portion of softened fibrin be examined microscopically, it will be found to be made up of a granular material, from which pus corpuscles, or corpuscles similar to them, are either entirely absent, or in which they occur but in very small numbers: now, with true pus, the reverse is the case; the corpuscles are its chief and most conspicuous element.

It is only by means of the microscope that the nature of softened fibrin can be ascertained; until within the last few years it has always been mistaken for true pus, and the occurrence of masses of fibrin thus altered in the blood-vessels has led to the opinion that the formation of pus in them is not an unfrequent event.

On the other hand, fluids are sometimes met with which look very unlike proper pus, and which are yet found on examination to be veritable pus. These facts show the necessity of a careful microscopic examination in all important and doubtful cases.

METASTATIC ABSCESSES.

Another notion, the erroneousness of which has been rendered manifest by means of the microscope, is that which has been entertained in reference to the removal of an abscess seated in one part of the body, and its subsequent deposition in another situation.

The knowledge of the existence of pus corpuscles in the fluid of abscesses, and the fact that no channels exist by which they can be conveyed bodily from one part of the system to another, clearly show that any such translation of the matter of an abscess as that presumed is an occurrence beyond the range of possibility.

Abscesses may indeed be re-absorbed into the system, as daily observation teaches us to be the case, and other purulent depositions take place subsequently to the resorption of the matter of the first abscess; but the elements of pus, and assuredly its solid constituents, are not carried into the constitution bodily and without alteration; the corpuscles doubtless become disaggregated, and in all probability reduced to a fluid state previous to absorption, so that it cannot be the same purulent matter which constitutes the pus of the supposed metastatic abscess.

The simultaneous or consecutive occurrence of abscesses in different parts of the body, may be satisfactorily explained by reference to the condition of the system, or perhaps more immediately of the blood itself, which is evidently charged with purulent matter, and of which it relieves itself by the formation of abscesses.

VENEREAL VIBRIOS.

M. Donné has discovered in the pus of syphilitic primitive ulcerations, and of chancres which have not been treated with topical applications, numerous vibrios of excessive tenuity. (See Plate XIII. *fig.* 6.)

These vibrios are not encountered in the pus of secondary chancres, nor even in that of buboes, which, according to the experiments of M. Ricord, is capable of giving origin to a chancre by inoculation.

Neither are they to be met with in the pus proceeding from wounds, nor in fœtid pus altered by the contact of the air.

Again, in the instances in which suppuration has been artificially excited around the edge of the *glans penis*, the ordinary situation of primary syphilitic ulcerations, the vibrios are invariably found to be wanting in the discharge thus created. This experiment proves that locality has nothing to do with the development of the vibrios.

Finally, if inoculation be practised with the pus of a chancre containing the vibrios, the matter of the pustule resulting from the inoculation will also be found to contain the animalcules.

Now, the inference to be deduced from these several facts and experiments is, that if the vibrios in question be not intimately connected with the propagation of the syphilitic virus, that the matter of syphilis is at least peculiarly fitted for their development.

It is probable that the presence of these vibrios accounts, in a great measure, for the beneficial effects of topical applications, which act by killing the animalcules.

Art. V. MILK.

The general aspect and qualities of milk are known to all; they need not therefore be here detailed.

Healthy and fresh milk, when submitted to the action of test paper, exhibits an alkaline reaction: in states of disease, however, and some time after its removal from the mammary gland, it frequently manifests more or less of an acid reaction.

Like the other fluids which have as yet been described in this work, milk is made up of two distinct elements, the one fluid, the serum,—the other solid, the globules; these, a few hours after its abstraction from the system, and when left at rest, undergo to a certain extent a spontaneous separation from each other, the larger globules ascending to the surface forming a scum or cream, while the smaller remain diffused through the subjacent serum.

The following analyses will serve to give an idea of the composition of milk.

The relative proportions of the organic constituents of human milk are thus estimated by Simon:

88·06 water.
3·70 caseine.
4·54 sugar.
3·40 butter.
0·30 salts, extractives, &c.

The inorganic components of the milk of the cow are computed as follows by Haidlen:

Chloride of sodium - -	0·024.
Chloride of potassium - -	0·144.
Soda - - - -	0· 42.
Phosphate of lime - - -	0·231.
Phosphate of magnesia - -	0·042.
Phosphate of the peroxide of iron -	0·007.

From the above brief sketch of the constitution of the milk, it will be seen that a very close analogy exists between that fluid and the blood: like it, the milk is made up of two parts, the one solid, the other liquid; like it too, it contains all the elements requisite for nourishment and developmeent, it serving for both during a very long period of the life of the human species.

THE SERUM OF THE MILK.

The separation of the serum and the globules, accomplished in an imperfect manner naturally, is more completely effected artificially by filtration, the serum, by means of the ordinary filtering paper, may be obtained transparent and colourless, almost free from globules, these being for the most part retained upon the filter.

It may however be observed, that the first portions of serum which pass through the paper will be more or less coloured in consequence of their containing a certain number of the smaller globules which had escaped through the interstices of the paper; these coloured and semi-opaque portions of serum should be rejected.

The serum contains dissolved in it the sugar, and the principal portion of the cheese of milk, as well as certain salts, the principal of which are pointed out in the analysis of Haidlen.

The cheese or caseine is an animal principle, which in its properties approaches closely fibrin: it is precipitated by the mineral, the acetic, and the lactic acids.

Although the greater portion of the caseine exists in the milk in a fluid condition, M. Quévenne appears to have established the fact, that it is also present in a solid state in the form of globules, these being exceedingly small and refracting but slightly the light; the same globules may also be detected in recently precipitated cheese. (See Plate XV. *fig.* 5.)

M. Donné has shown that these cheese globules may be demonstrated by the process of filtration; thus, the first few drops of the milk of the cow, the ass, or the goat, which pass through the filter, and which are generally white and opaque, being rejected, and the second portion of filtered milk being preserved and allowed to remain undisturbed for a few minutes, it will be seen to separate into two parts, the inferior of which is clear and transparent, while the superior is somewhat opaque; now if a drop of the fluid of this inferior layer be examined with the microscope, it will be found to contain an innumerable quantity of globules of exceeding minuteness and refracting the light but feebly, as well as occasionally other globules more rare, larger, and refracting the light very strongly; the former are the cheese globules, and the latter the proper milk globules.

THE GLOBULES.

It is to the presence of the globules which occur in such vast quantities in each drop of healthy milk that the colour and opacity of that fluid is due.*

These globules are of perfect rotundity, their surface being smooth, presenting a pearly aspect, and refracting the light strongly; the circumference of each globule is dark and the centre light: the globules vary greatly in size; the smallest, which are in active molecular movement, being reduced to mere points and not exceeding the $\frac{1}{18000}$ of an inch, the largest frequently attaining the $\frac{1}{2000}$ of an inch, and the medium size ranging between the $\frac{1}{4000}$ of an inch in diameter and the $\frac{1}{4300}$. (See Plate XIV. *fig.* 1.) In milk which is healthy the globules float freely in the serum, and do not adhere to each other.

Such is the form, appearance, and variety of size exhibited by the milk globule; much difference of opinion has existed in reference to its organisation, some observers conceding to it a very complex structure, others denying it even the most simple organisation.

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* Leeuwenhöek first clearly indicated the existence of these globules in the milk in the following terms: "Vidi multos globulos, similes sextæ parti globuli sanguinei; et etiam alios, quorum bini terni aut quaterni se invicem modo attingebant, fundum versus descendere; et multos variæ magnitudinis globulos in superficie fluitantes, inter quos posteriores adipem sive butyrum esse judicabam."

Some of the more remarkable of the opinions entertained by the more noted investigators may here be referred to.

According to Turpin, "the structure of the milk globule consists of two spherical vesicles fitting the one into the other, and enclosing in their interior very fine globules and buttery oil."[*]

Mandl says, "the globules of milk ought then to be considered as organised corpuscles, composed of a membrane probably formed of cheese, and of contents which constitute the butter."[†]

Henle writes, the globules of milk "are not simple molecules of grease, and have an independent membrane surrounding them[‡];" this he elsewhere states to be probably composed of caseine, in which respect there is an agreement of opinion between Henle and Mandl.

The complex structure ascribed to the milk globule by Turpin it is altogether impossible to demonstrate; and the experiments and observations which have hitherto been made in reference to its constitution are entirely opposed to his view, which may safely, therefore, be considered to be incorrect.

Mandl founded his belief of the existence of a distinct membrane enveloping the globules mainly on the following observation:— He remarked that if a little drop of milk be compressed strongly between two plates of glass, the upper plate at the same time being drawn over the surface of the other in a straight line, the milk globules will be broken up by the compression, and drawn out into a certain form: if a magnifying glass be applied to the globules thus compressed, they will be seen to present the appearance of long pale and straight lines, with smaller straight lines placed usually at right angles to the larger ones. "These little lines," he says,

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[*] Annales des Sciences Naturelles.

[†] Anat. Micros. p. 53.

[‡] Anat. Gen. t. vii. p. 522.

"are nothing else than the curled membranes of the globules, the contents of which, the butter, constituting the long streaks: we may easily convince ourselves of this by adding a little water. The streaks disappear, and we see in their place oleaginous drops of different forms, while the little membranes remain either attached to the glass or indifferently curved, swimming in the serum. These membranes are insoluble in ether, which dissolves the drops."

These observations of Mandl, presuming for a moment that they are accurate in every particular, are yet insufficient to prove the existence of a distinct membrane surrounding the globules, although they certainly would be so, if correct, to establish the fact that they are constituted of two different substances, the one of which is soluble in ether and the other insoluble. Had iodine been employed, and had it been imbibed by the supposed membrane, and turned of a deep brown, the reality of the existence of the membrane in question might have been considered as demonstrated: but we know that iodine does not affect the colour of the milk globule in the least.

I am far, however, from attaching the smallest importance to the experiment of Mandl, because I conceive that he has misinterpreted the appearances which he noticed. The larger streaks are not constituted of a single elongated globule, but are made up by the union of several milk globules, as is evident, first, from the size of the streaks, and, second, from the traces which they bear of such a composition in themselves; as, for example, the occurrence of contractions at certain intervals, while the smaller lines, and which are most generally absent, are formed usually by other globules of less size joining at an angle the larger streaks. The solubility of the one in ether and the insolubility of the other in that re-agent, I have not been able to observe.

The opinion of Henle that the milk globule is furnished with an envelope rests chiefly upon the manner in which acetic acid acts upon it.

Henle thus describes the effects of the application of acetic acid: —

"Treated by dilute acetic acid, the globules of milk undergo, little by little, a remarkable change, some of them become oval or take the form of a biscuit; upon others, appear gradually on one or many points a smaller globule, which rests upon the margin and increases in an insensible manner." * * * "If more acetic acid be added, the milk globules appear, as it were, melted down with smooth but irregular borders: they approach the one to the other, and unite into large masses, which resemble perfectly melted fat which has run along in an irregular manner. When to a drop of milk are added two drops of concentrated acetic acid, and the mixture then placed under the microscope, we no longer perceive any regular globule of milk, or, at least, we discover but very few—the most are reduced into one or several irregular particles, which, with the naked eye, may be distinguished upon the surface of the drop which otherwise has become clear. The same changes are produced in the space of a few days, when the milk, abandoned to itself, becomes acid by the metamorphosis of its sugar."*

These ingenious observations of Henle, like those of Mandl, are yet insufficient to demonstrate the existence of a distinct and organised membrane surrounding the milk globule, although they would be assuredly so, if correct, to render it quite certain that it is enveloped with a coating of a material very distinct from fat, and probably of the nature suggested by Mandl and Henle.

Here, again, however, it becomes a question whether the appearances noticed by Henle have not been misinterpreted, and whether the internal buttery substance does really protrude through apertures in the envelope of the globule occasioned by the action of acetic acid: in the first place, it seems to me that the milk globules are too small to allow of the determination of the point in question with any degree of certainty; and, secondly, that in those instances in which observers might fancy that an escape of the included substance of the globule through its envelope had really occurred, such an appearance is, in all probability, due to the adhesion together and partial fusion of two or more globules. (See Plate XV. *fig.* 4.)

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* Henle, Anat. Gen. p. 521, 522.

There are other observers again, as Wagner, Nasse, and Quévenne, who would deny to the milk globule all organisation, and who regard it as of a perfectly homogeneous nature.

The truth in this instance, as in so many others, would appear to lie in the mean. That the milk globule is not provided with a distinct and separate membrane, similar to that of the mucous corpuscle, is proved by the impossibility of demonstrating the existence of any such structure, as well as by the absence of a double line around its margin, the non-effect of iodine, and the coalition of the globules resulting from pressure, first observed by Dujardin.

That it is not constituted of a single perfectly homogeneous substance is also demonstrated by the observations of Mandl and Henle, and especially by those of the latter observer on the effects produced by acetic acid.

That the milk globule is not wholly composed of fatty matter is shown by its insolubility in boiling water raised to a very high temperature, in boiling alcohol, in the alkalies, and by the effects of the application of acetic acid. Ether dissolves the milk globules: their solution, however, it does not entirely accomplish on its first application, although the ether, the moment it comes in contact with the globules, causes them to lose their rotundity, to fall down, and to run together into masses of various sizes, but most of which still present a circular outline.

If a drop of milk be examined microscopically, after its treatment by ether, a hasty observer might conclude, from noticing so many of the circular masses alluded to, that the re-agent had not exerted any influence on the milk globules, and that these masses were the unaltered globules. This view, however, a little reflection would soon show to be incorrect; for many of the circular bodies now noticed on the field of the microscope are larger than even the largest milk globules, and all of them are flat and semi-fluid. (See Plate XV. *fig.* 3.)

The several facts now adduced, while they prove that the milk globule is not organised in accordance with the interpretation of the word organisation usually given, yet seem sufficient to establish the fact that it is composed of two distinct organic products, the one internal and fatty, and the other external and possessed of properties distinct from fat.

This explanation of the constitution of the milk globule serves to explain also satisfactorily the facts above alluded to, viz. the non-action of boiling water, alcohol, and alkalies, all of which affect more or less fat, as also the slower operation of the ether: it also shows why boiling alcohol should immediately dissolve the milk globules, to which a little acetic acid had been previously added, this latter re-agent first removing their outer coating, which is insoluble in alcohol.

Between the globules of the previously described fluids, those of the lymph and chyle, of the blood, mucus and pus, and the globules of milk, no structural or functional relation whatever exists, the former being complex and definite organisations or cells, and the latter constituted of two distinct substances indeed, yet want entirely the attributes of cells, being destitute of nucleus and cell wall.

It is of the globules just described that the cream is constituted, their accumulation on the surface of the milk being due to their lighter specific gravity; it is also by their incorporation with each other, and which is effected by the operation of churning, that butter is formed.

COLOSTRUM.

The milk which is secreted the first few days after childbirth has been denominated colostrum: it differs very considerably from ordinary milk, being of a yellow colour, of a viscous consistence, and containing a very large proportion of milk globules, which give rise to the formation upon it of a thick layer of cream; when treated with ammonia it becomes glairy and tenacious.

Corresponding with the outward characters of the colostrum, there are others indicated by the microscope not less remarkable: thus the larger true milk globules which occur in it are but ill defined, being irregular in form and size, appearing as though they were but imperfectly elaborated, and presenting rather the aspect of oil globules, while the smaller ones are like a fine powder strewn through the serum, and adhering to the surface of the larger globules, which also, in place of floating freely and separately in the serum, are agglomerated together as if held in union by some viscous material. (See Plate XIV. *figs.* 4 and 5.)

But besides the state of the ordinary milk globules just described, there are found in the colostrum peculiar corpuscles of a totally distinct structure: these were first discovered and described by M. Donné, who has denominated them "*Corps granuleux.*"

These corpuscles are mostly several times larger than the milk globules, are less regular in form, although usually more or less spherical in outline, and present a uniformly molecular aspect and a yellow coloration; the edges of the corpuscles sometimes appear smooth as if possessed of an envelope, at others, their margins are rough, and convey the impression that they are destitute of any external covering. (See Plate XIV. *figs.* 3 and 4.) Occasionally one or more milk or oil globules are imprisoned in the substance of the corpuscles, which then occupy the position, although they do not discharge the office, of a nucleus.

Some difference of opinion is entertained respecting their intimate structure: Gueterbock, and probably Donné*, conceive that they are furnished with an investing membrane, and therefore that they are veritable cells, while Henle† regards them as masses or aggregations of granules agglomerated together in an amorphous and mucoid substance; an opinion in which I concur.

Donné states that the colostrum corpuscles are soluble in ether, and therefore that they are of a fatty nature: the fact of their solubility, however, seems to me to be difficult to verify; and from observations which I have made, I cannot help thinking that this point is scarcely as yet established. Certain it is that corpuscles larger than mucous globules, and in every way similar to the colostrum corpuscles, save that traces of nuclei may be detected in them, appear in colostrum treated with ether.

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* Cours de Microscopie, p. 401.

† Anat. Gen. t. vii. p. 525.

The "*Corps granuleux*" are insoluble in the alkalies *, are coloured brown by iodine, and the substance which unites these granules is dissolved by acetic acid. †

The state of the milk just described does not continue without alteration, each condition which has been alluded to undergoing a daily modification: thus the milk globules from day to day acquire greater uniformity of size and shape, they no longer adhere together, but float freely and singly in the serum, which does not become viscid on the addition of ammonia, the smaller dust-like globules also altogether disappearing; at the same time the number of the colostrum corpuscles diminishes until at length none exist. (See Plate XIV. *fig.* 1.)

These several changes are all accomplished in the course of a few days, so that by the end of the twenty-fourth day, the milk has usually entirely passed from the condition of colostrum, and presents only its ordinary characters. The colostrum, however, does not always pass through its various modifications in the time specified, it may do so in either a shorter or a longer period than that stated: thus the existence of the milk in the form of colostrum can scarcely be regarded as affording any very certain test whereby the age of the milk may be determined.

The colostrum corpuscles would appear to be almost peculiar to the human subject, for while their presence in the milk of woman is almost constant, their occurrence in that of animals, as the cow, the ass, and the goat, is rare and exceptional.

Professor Nasse states that they disappear sooner in women who have borne many children than in those who have had but a single child.

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* Donné, loc. cit. p. 401.

† Henle, loc. cit. t. vii. p. 525.

Mucous corpuscles are also occasionally encountered in the colostrum. They are, however, neither very generally present, nor do they occur in any very great numbers.

The colostrum, or first milk, is possessed of purgative qualities.

PATHOLOGICAL ALTERATIONS OF THE MILK.

Persistence of this Fluid in the condition of Colostrum.

It has been stated, that usually by the end of the twenty-fourth day after childbirth, and frequently at a much earlier period, the colostrum has lost all its distinctive characters, and the milk has arrived at its perfect condition.

This transformation of the colostrum into fully elaborated milk, it has been observed, is not always effected in the time named: it may be accomplished in either a shorter or a longer period; thus the milk in some cases loses the chief characters of colostrum in as short a space of time as three or four days, while in others it retains them for months after the birth of the child, and even until the end of lactation.

This persistence of the milk in the state of colostrum may be present without any suspicion of its existence being entertained, the milk exhibiting its ordinary outward appearances.

It is therefore, only by means of the microscope, that its true condition can be ascertained. Examined with this instrument, the characteristics of colostrum will be detected; thus the globules which do not float freely in the serum, and which are large and ill-formed, will be seen to adhere together in groups, as though held in union by some viscous substance, and intermixed with them will be noticed numerous colostrum corpuscles.

It cannot be doubted but that such persistence of the milk in the form of colostrum exerts a most injurious effect upon the child: the colostrum is, as we know, possessed of purgative properties; these during the first days of the life of the infant are necessary, their continuance cannot but impair its strength and health.

Recurrence of Colostrum.

M. Donné has established the interesting fact that milk which has entirely lost the character of colostrum, and which has reached its perfect maturity, may again pass into the state of colostrum at any period during the course of lactation.

Thus the milk which had at one time presented the constitution of perfectly formed milk has been seen by M. Donné to acquire gradually that which is indicative of the colostrum, it becoming viscous, and the globules contained in it, instead of floating freely and singly in the serum, uniting with each other, forming irregular masses, the granular and mucous corpuscles at the same time being present in it in considerable quantities.

In the instances in which the recurrence has been observed, engorgement of one or both of the mammary glands has usually preceded it.

When but one gland is affected, the milk of that gland only presents the characters of colostrum, that of the opposite side retaining its usual properties and constitution.

The recurrence of the colostrum would appear to depend, as a cause, either upon lesion of the mammary gland, or upon a deranged or vitiated condition of the health.

Influence of prolonged Retention of the Milk on its Constitution.

M. Peligot has made the observation, important in a practical point of view, that the milk which has been allowed to remain for a long time in the breast becomes thin and watery, an effect which is contrary to that which occurs in reference to most other secretions of the economy, the urine and the bile, the density of which is heightened by retention.

Thus if the milk abstracted at one time, and which has been long secreted, be divided into three parts, each being received successively into a distinct vessel, the first milk will seem to be poor and watery, the second more rich, and the third the most so of the entire. The first portion is to be regarded as that which has been longest formed, and the third as the most recently secreted.

The knowledge of the above fact leads to one practical result in the case in which the milk is too rich for the digestive powers of the child; thus by allowing such milk to remain for a longer period than usual in the breast, a fluid of lighter quality and less abounding with nutritive principles will be obtained.

A second effect of prolonged retention or engorgement of the milk in the breast is to occasion the aggregation of the globules into masses. (See Plate XIV. *fig.* 6.)

Pus and Blood in the Milk.

Having now described those constituents by the combination of which milk is formed, as well as the several conditions in which these may be encountered, we may next refer to those structures which occasionally occur in milk as the result of disease.

Thus the corpuscles of both pus and the blood are sometimes encountered in the milk, those of the former fluid occurring much more frequently than those of the latter.

The puriform matter which issues from the breast in cases of abscess of that gland is made up of a mixture of pus and milk globules, with occasionally blood discs. (See Plate XV. *fig.* 1.)

But both pus and blood corpuscles, the latter very rarely, may be contained in the milk which issues from the breast through its natural channels.

I was so fortunate as to meet with an excellent example of blood in the milk, the occurrence of which is so rare that Donné, at the period of the publication of the "Cours de Microscopie," and with all his researches on the milk, had never encountered a single instance of such pathological alteration in the human subject. The case in which this occurred was that of a young woman confined of her first child; the milk not appearing at the usual time the friends became anxious, and one of them, more officious and more ignorant than the rest, had the nipples drawn with such vigour and effect as to cause the extraction of a liquid half blood and half milk. (Plate XV. *fig.* 2.) The occurrence of blood corpuscles in the milk can only take place as the consequence of a rupture of some of the smaller blood vessels which are distributed through the mammary gland.

The above facts clearly show the impropriety of applying an infant to the breast in cases of inflammation and suppuration in that organ.

Not the least difficulty need be experienced in the detection of pus and blood corpuscles in the milk, their form and structure being so totally dissimilar to those of the proper milk globules. Re-agents also affect the different kinds of corpuscles differently. Thus the milk globules are soluble in ether, which does not materially affect the pus and blood corpuscles, the latter of which is dissolved by acetic acid, and the former only by the caustic alkalies.

The Milk of Syphilitic Women.

M. Donné has made repeated attempts to discover in the milk of women labouring under syphilis in different forms, some element which would account for the transmission of the affection from the mother to the infant. These endeavours were, however, entirely fruitless; nor is this result other than what might have been anticipated, for it is scarcely to be supposed that the venereal virus exists anywhere in a tangible form, and if it really does so, it would still be a matter of impossibility to point out the channels by which any solid matter could make its way through the system and mingle with the secretion of the mammary gland.

The Milk of Women in the Case of the premature Return of their Natural Epochs.

The milk of women in whom the natural periods have returned during the course of lactation, has likewise been carefully examined. Except in a single instance, however, it has not been found to present any thing remarkable in its characters. In the case referred to, it had degenerated to the condition of colostrum, and contained the granular colostrum corpuscles.

THE MILK OF UNMARRIED WOMEN.

The breasts of many women who have not been married are frequently found to contain an abundance of milk, and from those of most, more or less of a milky fluid can be obtained.

This milk exhibits all the characters of colostrum, containing even the peculiar corpuscles which distinguish that condition of the milk; it is therefore, like the first milk, to be regarded as an imperfectly elaborated substance.

THE MILK OF WOMEN PREVIOUS TO CONFINEMENT.

The breasts of most women during the last few weeks of gestation contain more or less milk, which also presents all the characters of colostrum.

The quantity of milk contained varies greatly; in some cases a few drops of a milk-like fluid only can be obtained; in others it is more abundant; and again, in other instances, it is still more plentiful, and rich in quality.

The question may be asked, does there exist any relation between the quantity and condition of the milk before confinement, and its state when it has arrived at perfection after this event has occurred? In other terms, can one pronounce, by the milk in the breasts, beforehand, whether a woman will have a sufficient quantity of milk to nourish her infant?

This question, which so often presents itself to the consideration of the medical practitioner, M. Donné has discussed at some length, and to it he replies thus.

"The secretion of the mammary gland," he says, "is after confinement in constant relation with the state which it presents during gestation, so that it is possible to know in advance, by the observation of its characters during the last months of pregnancy, what its condition will be when it shall have acquired all its activity after parturition."* This law, he states, is so general that in the sixty observations which he has made on women of all ages and temperaments, he has met with but two or three exceptions.

Pregnant women Donné divides into three classes, founded upon the characters presented by the colostrum during the last months of gestation.

1st. Those in whom the secretion is small, and the viscous liquid contains scarcely any milk globules, mixed with a very few colostrum corpuscles.

2nd. Those in whom the colostrum is more or less abundant, but poor in milk globules, which are small, ill-formed, and containing also colostrum and mucous corpuscles.

3rd. Those in whom the colostrum is very abundant, rich in milk globules, which are of good size, and unmixed with any other corpuscles save those proper to the colostrum.

Now the indications to be deduced from the different states of the colostrum just described are —

That the first state appertains to women in whom the secretion of milk after childbirth is either very little, or in whom there is produced but a serous milk, poor in nutritive elements, and therefore insufficient for the nourishment of the child.

That the second condition indicates those in whom the secretion of milk after confinement is either small or abundant in quantity, but which is always poor and serous.

That the third state of the colostrum belongs only to such women as have an abundant supply of milk of good quality.

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* Cours de Microscopie, p. 406.

THE MILK OF WOMEN WHO HAVE BEEN DELIVERED, BUT WHO HAVE NOT NURSED THEIR OFFSPRING.

The mammary gland of women who have borne children, but who have not nursed them, is frequently found to contain milk many months after confinement.

This milk always presents the characters of colostrum.

MILK IN THE BREASTS OF CHILDREN.

A milk-like fluid can frequently be expressed from the breasts of infants and young children, both male and female.

This fluid, examined microscopically, has been found to exhibit all the characters of ordinary milk; and, in some cases, the colostrum corpuscles have even been detected in it.

DIFFERENT KINDS OF MILK.

The milk of one mammiferous animal resembles so closely that of another that it is often a matter of impossibility to distinguish, either with the naked eye or by means of the microscope, the different kinds of milk.

The milk of the ass may, however, be generally known by its watery aspect, its bluish tint, and its lightness; that of woman by the promptitude with which the layer of cream is formed upon it; but it is, above all, by the taste that the several kinds of milk are characterised: thus, the taste of the milk of the cow can scarcely be confounded with that of the ass or goat, nor can the flavour of the milk of woman be mistaken for that of any of these.

The microscope aids but little in the discrimination of the different kinds of milk: the globules of the milk of the goat are certainly smaller than those of the other species named, and those of the ass are less numerous; nevertheless these characters are so little constant that they are not, in many instances, sufficient to distinguish them from the milk of the cow or of woman.

The number of globules contained in the milk of different animals doubtless varies considerably; but there is as much variation in this respect as in those just referred to; and, therefore, this difference is not sufficient to distinguish the several kinds of milk.

RELATIVE PROPORTIONS OF THE ELEMENTS OF MILK.

Chemical analysis indicates a very great variety in the relative proportions of the different nutritive ingredients of milk; and this, not merely with respect to the milk of different animals, but also in reference to that of the same species, and even of the same individual, at different times.

The truth of these remarks will be evident from an examination of the following analyses:—

Analysis of the milk of woman by Peyen.

Butter - - - -	5·16
Sugar and cream - - -	7·80

Analysis of the same by F. Simon.

Water - - - -	88·06
Caseine - - - -	3·70
Sugar - - - -	4·54
Butter - - - -	3·40
Salts, extractive matter, &c. - -	0·30
	100·00

Analysis of the milk of woman, the cow, the goat, and the ass, by Meggenhofen, Van-Stiptrian, Liuscius, and Bonpt, and Peligot.*

	Woman.	Cow.	Goat.	Ass.
Butter	- 8·97	2·68	4·56	1·29
Sugar	- 1·20	5·68	9·12	6·29
Casine	- 1·93	8·95	4·38	1·95
Water	- 87·90	84·69	81·94	90·95

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* This analysis is copied from the "Cours de Microscopie" of Donné.

It will be seen from the above analyses that the milk of woman is the richest in butter, while that of the ass contains the smallest amount of that element.

The assertion made by Donné, that the quantity of butter in the milk of the *same species* stands in relation with that of the other essential ingredients of the milk, although supported by the researches of Peyen and Peligot is contradicted by those of F. Simon. According to the analyses of Simon, the quantity of sugar is greatest immediately after delivery, a few days being passed this diminishes, and the amount of caseine, which was at first very small, undergoes a gradual augmentation. The butter Simon considers to be the most variable element of the milk, its variations not being reducible to any law.

The relative proportion of the different ingredients of the milk of animals may be modified, and almost altered, at will, by the adoption of a certain regimen.

GOOD MILK.

The purity and the richness of milk were formerly estimated by its specific gravity, which is about 1·032; if the milk was poor in cream, or if it was diluted with water, it was supposed that the gravity of the fluid would be in the first case increased, and in the second lessened.

The cream being the lightest element of the milk, its deficiency or its abtraction would, of course, increase the density of the remaining fluid, and the addition of water, after the removal of the cream, which is also of less weight than milk which is even pure and rich, would, of course, raise the gravity of the milk either up to or even beyond its natural weight.

Now, the abtraction of the globular element of the milk and the addition of water are the two frauds most frequently had recourse to; and they are of such a nature as to elude detection by reference to the specific gravity of the milk, when they are both put in practice in combination.

The specific gravity test of the purity and richness of milk is, then, one which is fallacious, and therefore but of very little value.

It has been proposed by M. Quévenne, not merely to estimate the specific gravity of milk, but also to measure the layer of cream which forms upon it by repose. This ingenious method is scarcely more to be depended upon than the preceding, and is put at fault by the fact that the addition of water favours the ascension of the cream.

Thus, the layer of cream formed on milk to which water has been added will be thicker than that of unadulterated milk, this effect being the consequence of the lessened specific gravity resulting from the addition of the water.

Donné has made the statement, which is borne out by the analyses of MM. Peyen and Peligot, that the globular or buttery element of the milk stands in relation, in the milk of the same species or animal, though not in different species, with the other nutritive ingredients of milk, the cheese and the sugar.

The analyses referred to are the following: —

Milk of woman analysed by M. Peyen.

Butter - -	5·16	5·18	5·20
Sugar and cheese -	7·80	8·10	9·80

Milk of asses analysed by M. Peligot.

Butter - -	1·55	1·40	1·23	1·75	1·51
Sugar and cheese	10·11	7·97	7·34	8·25	7·80

Donné, therefore, proposes to estimate the purity and the richness of milk by means of the globular element contained within it. The eye alone will, in some measure, indicate the number of globules contained in the milk; for, since the opacity of milk is due to the presence of the globules, it may be concluded that the milk which is white and opaque is rich in globules, while that which is watery and transparent is poor in the same.

The microscope, however, is a more certain means of determining the number of the globules, although by means of this instrument we can only arrive at an approximative knowledge of their amount.

In order to estimate as nearly as possible the number of globules existing in the milk, M. Donné has invented an apparatus which he has termed a lactoscope. By means of this instrument the milk can be examined in very thin layers, and in proportion to the opacity of the milk spread out into such layers, so will be its richness, the deeper the stratum the richer the milk.

There is one fallacy attending the use of this instrument which requires to be noticed: this, however, is one which has reference to its employment in testing the quality of the milk of the cow, the ass, and the goat, and not of the milk of woman.

The milk of commerce is frequently adulterated with substances such as chalk and flour, which are intended to heighten its colour and opacity; the presence of these then in the milk would, to a certain extent, lessen the value of the opinion to be deduced from an examination of the milk with the lactoscope of Donné.

The effect, however, of the admixture of chalk and flour in heightening the opacity of milk is not so considerable as might be supposed, and this is especially found to be the case when it is spread out in thin layers as in the lactoscope. Moreover, the presence of an insoluble substance in the milk might be detected by means of the microscope.

Applied to the examination of the milk of woman, the lactoscope would not be subject to the above fallacy.

Having now shown that the globules constitute an important element of the milk, and the methods by which their number may be ascertained, we may, in the next place, describe more particularly the qualities of good milk.

Healthy milk may be defined to be an alkaline fluid, having a specific gravity of about 1·032, holding in suspension numerous perfectly spherical and discrete globules, soluble in ether, and therefore of a fatty nature, — and in solution cheese and sugar, together with various salts.

If, on the contrary, the milk be viscous or acid, if the globules be ill formed or few in number, if they adhere together in masses and do not roll freely and separately in the serum, if also this contain the colostrum corpuscles, then the milk is either imperfectly elaborated or diseased.

Whenever the proper globules of the milk occur abundantly, are of the usual size, and are equally diffused throughout the serum, we may conclude that the other nutritive elements of the milk are likewise present in due proportion. (See Plate XIV. *fig.* 1.)

It must be held in mind, however, that the milk of different animals does not contain normally the same relative amount of nutritive ingredients: thus the milk of woman is especially rich in cream, while that of the goat and ass is but poor in that element.

POOR MILK.

Not unfrequently the milk is found to contain a less quantity of globules than ordinary: the milk in which a deficiency of its globular element exists appears watery and transparent, and is also usually of greater specific gravity than good milk. (See Plate XIV. *fig.* 2.)

This condition of the milk is one of its most common as well as most serious states in its consequences to the child.

At the same time that the milk is poor in globules or in cream, the serum may be either deficient in quantity, or it may be in excess.

In either case, such milk, whether it be human or not, is deficient of the amount of the nutritive ingredients necessary for the growth and development of the child, which instead of increasing in size, daily diminishes, becoming faded and emaciated. In the instances in which milk containing a superabundance of serum is received into the stomach, that organ becomes distended and weakened by its engorgement with a fluid the digestion of which brings with it little or no nourishment.

An infant whose strength is reduced by the poverty of the milk given to it, is not unfrequently the subject of diarrhœa, which still further lessens its powers.

RICH MILK.

An opposite condition of the milk to that just described frequently exists, viz. that in which its nutritive principles are in excess, a fact which is most readily ascertained by an examination of the state of the globular element of the milk: this being superabundant, it may, as already shown, be concluded that the sugar and cheese likewise occur in unusual quantities. (See Plate XIV. *fig.* 5.)

This condition of the milk is not to be regarded as an alteration of its qualities, but merely as an exaggeration of them; nevertheless, it is one which is often incompatible with the well-being of the child. This rich milk is often too strong for the digestive powers of the child, whose nutrition in consequence suffers: it, moreover, is sometimes the occasion of colic and diarrhœa.

The state of the milk just noticed, and its consequent effects upon the child, may be modified and even entirely remedied by a judicious regulation of the diet as well as by permitting the milk to remain in the breast for a considerable time, the effect of which retention is to render it more watery; the infant, also, should not be allowed to take the breast except at long intervals.

At the same time that the globules are more numerous in milk which is very rich, they are also larger. The size of the globules is likewise found to undergo an increase from the first days of lactation, and this increase continues for some months afterwards: thus, the globules of the third month are larger than those of the first month, and those of the sixth month still larger, the number of the very small globules having diminished very considerably. The increase in the size of the globules referred to, is not, however, so uniform or so constant as to allow of the determination from it of the age of the milk.

ADULTERATIONS OF MILK.

There are but few articles of general consumption more adulterated, and on which more frauds are practised, than the milk.

The more usual substances employed for the purpose of adulteration are water, flour or starch, chalk, and the brains of sheep; of these, water is the one which is most frequently had recourse to, and which is the most difficult to detect.

The effect of water in altering the specific gravity of milk has already been referred to; and it has been shown that the result of its addition to milk, a portion of the cream of which has been abstracted, is to restore the specific gravity which usually belongs to it.

Donné has shown that however much the gravity of milk may vary, that the density of the serum of the milk is almost constant. This fact is interesting and important, for by a knowledge of it the deterioration of milk by its admixture with water or with some other substance of the same density with it may be ascertained. The serum is constantly heavier than water: adulteration with it would then cause the serum to exhibit a less specific gravity than that which should properly characterise it; the conclusion to be deduced from this circumstance being that the milk has been deteriorated, most probably, by the addition of water.

The adulterations with flour and sheep's brains are readily detected by means of the microscope. The fraud by the former may be recognised by the peculiar form of the flour granules, as well as by the action of iodine upon them (See Plate XV. *fig.* 6.); and that by the latter may be distinguished by the detection, in the fluid, of more or less of cerebral structure, and especially of the nervous tubuli.

The chalk in the milk is readily revealed by its effervescence with hydrochloric acid, as well as by its weight, which causes it to subside at the bottom of the vessel containing the milk.

FORMATION OF BUTTER.

Several explanations have been proposed with the view of determining the exact cause of the amalgamation of the cream globules with each other, and the formation of butter.

Some have supposed that the trituration to which the globules are subject in the churn determines their union and incorporation with each other; but it is known that the amalgamation is not a gradual process, as it would be were their union to depend upon trituration, but that it takes place in a manner almost instantaneous: moreover, agitation might fairly be presumed to have a contrary effect on the globules, which participate in the properties of oil, and that it would cause their further subdivision.

A second hypothesis conceives that a chemical alteration in the condition of the globules is determined by the presence of the air: this has been shown to be erroneous by the fact that butter will form *in vacuo.*

A third theory presumed that an acid state of the milk always preceded the formation of the butter: this notion is disproved, since butter is formed of cream, the alkalinity of which is purposely preserved by the addition of soda or any other alkali.

Donné thus explains the formation of butter: "The butter globules," he says, "are surrounded in the cream by cheese in a viscous state: this matter isolates the globules the one from the other, and is opposed to their union. The churning coagulates the cheese in which the globules are imbedded, and, once separated from this, the grease globules unite and agglomerate together easily."

It is doubtful how far this explanation, though more satisfactory than its predecessors, really accounts for the instantaneous formation of the butter.

MODIFICATIONS EXPERIENCED BY MILK ABANDONED TO ITSELF, AND IN WHICH PUTREFACTION HAS COMMENCED.

The first change which the milk undergoes subsequent to its abstraction from the system is that which has already been referred to, and which consists in the separation of the globular or buttery element of the milk from its other constituents, and its ascension to the surface of the fluid, where it forms the layer of cream; this change in the arrangement of the components of the milk is determined by the lighter specific gravity of the proper milk or butter globules.

All the milk globules do not, however, ascend and join those which constitute the cream: it is chiefly the larger ones which do so, the smaller remaining diffused through the subjacent milk, to which they impart the degree of opacity which belongs to it.

These smaller globules are not, however, equally scattered through the skimmed milk, the greater portion of them being spread through the upper stratum of it, and the lower appearing almost clear and transparent, containing but few butter globules, and these the smallest, as well as the minute cheese globules already described.

These changes consist merely in a different disposition of the normal constituents of milk, and are unaccompanied by any alteration in the constitution of its elements. The next series of alterations have reference to the decomposition of the milk, and are attended by changes in the actual state and composition of the milk.

The first change experienced by the milk indicative of commencing decomposition is that from an alkaline to an acid condition. This acidity, slight at first, goes on increasing until at length other alterations are produced; thus, the layer of cream becomes thicker and thicker, condenses itself into a mass, and finally presents almost the appearance of butter; at the same time the cheese is coagulated and precipitates itself to the bottom of the liquid: a portion of it, however, frequently remains suspended in the milk, in consequence of its retaining a number of butter globules, which lessen its specific gravity. Soon, however, other changes show themselves, still more indicative of putrefaction: the layer of cream swells up, becomes more yellow, and a fungus springs up upon its surface, the *Penicillum glaucum*. This at first presents the appearance of white velvet; but afterwards as soon as the fungus has reached the period of fructification it assumes a green colour.

The idea of M. Turpin, that this fungus had its origin in, and was developed from, the milk globule, scarcely requires a serious refutation.

At the same time the odour of the milk undergoes a complete change: sweet when it is fresh, it becomes acid as it decomposes, and gives out more especially the smell of cheese.

Examined with the microscope, in addition to the fungus alluded to above, numerous infusory animalcules will likewise be detected.

Now the changes above described, and which are experienced by the milk of every animal, will be more clearly understood if the milk be previously filtered, and the butter and the serum being obtained separately, those alterations which ensue in each be noticed.

It will be observed, that it is the butter, or non azotised substance, which undergoes the acid fermentation, and on which the fungi are principally and most generally developed.

The serum, on the contrary, becomes alkaline and exhibits the ammoniacal or putrid fermentation, this depending upon the azotised principle which it holds in solution, viz. the cheese.

It will be remarked, also, that the serum in changing does not exhibit the striking odour of cheese which the milk itself gives out under the same circumstances, and from which it may be concluded, that a certain amount of butter is necessary to produce the peculiar smell of cheese.

The phenomena to which the putrefaction of milk give rise result, then, from two kinds of fermentation; the acid, in which the buttery element of the milk is concerned, and the alkaline, resulting from the decomposition of the caseine.

THE OCCURRENCE OF MEDICINES, ETC. IN THE MILK.

The extreme rapidity with which the formation of milk from the blood is effected is most surprising, and is only equalled in the animal economy by that with which the urine is itself secreted.

The rapid secretion of milk from the blood serves to explain the almost immediate appearance in the former fluid of various chemical re-agents and articles of food introduced into the system through the medium of the stomach.

Thus, many articles taken as food, or as medicine, have been detected in the milk a few minutes after they have been received into the stomach. The colouring matter of madder root, the odorous principles of garlic, turpentine, &c., neutral salts, nitrate of potassium,—have all been encountered in the milk.

These particulars show the necessity of great precaution in the prescribing of remedies for a nursing mother, and explain the great susceptibility of children at the breast to the influence of the medicine administered to the parent.

Art. VI. THE SEMEN.

The seminal fluid, arrived at its perfect state, as when it is ejaculated, is not a simple liquid, the secretion of a single organ, but is compounded of the several products furnished, though not in an equal proportion, by the testicle, the epididymis, the vas deferens, the prostate gland, the glands of Cowper, the vesiculæ seminales, and the follicles of the urethra.

But the spermatic fluid is also in another sense a compound product; thus, like the fluids which have already been described, it is made up of a liquid and a solid element, the latter consisting of numerous organised particles suspended in and diffused through the former; these particles are of more than one kind, and may be divided into those which are essential and those which are non-essential: those which belong to the first category are the spermatozoa, the seminal granules, and the spermatophori; and those which appertain to the second, are the mucous corpuscles and epithelial scales: these last constituents occur but seldom, and are difficult to discriminate from the seminal granules and the spermatophori.

The spermatic fluid, resulting from the above combination of solid and fluid elements, is then usually a thick semi-opaque and gelatinous-looking substance, of a greyish, whitish, or yellowish tint, and endowed with a peculiar and penetrating odour, which Wagner states does not belong to the sperm previous to its departure from the testicle itself.

It is, above all, the spermatozoa, from the liveliness of their motions, the variety of their forms, the peculiarity of their developments, and their functional importance, which impart interest to the study of the spermatic fluid, and which the microscope has shown to occur in it in such vast numbers.

SPERMATOZOA.

The spermatozoa * are the most distinctive, as well as the most interesting, constituent of the semen, and once detected, the nature of the fluid under examination can no longer be doubted.

Each spermatozoon consists of two portions, an expanded part, to which has been assigned the several names of "disc," "head," and "body," and an attenuated extremity, which is called "tail."

The spermatozoa present great varieties in size and form: these variations are for the most part constant in a natural family and genus, and are always so in a simple species: thus a knowledge of the particulars of form and size of the seminal animalcules is frequently sufficient to distinguish many groups, genera, and individuals from each other: spermatozoa are, therefore, capable of affording assistance in classification.

Form.

In the class Mammalia especially, with which, in this paper, we are chiefly concerned, the spermatozoa vary greatly in shape; but in several of the more natural groups of that class, one determined form and magnitude may be detected throughout the different species constituting such groups.

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* In reference to the discovery of the spermatozoa, the following passages are contained in Leeuwenhöek (Opera, t. iv. p. 57.) : — " N. Hartsoeker (Præven der Doorsichikunde, s. Specimina dioptrices, p. 223.) says that he made known the spermatic animalcules in 1678, in the " Journal des Savants." I attribute the discovery to Hamm. He brought me in 1677 some gonorrheal matter, in which he found animalcules with a tail, which, according to him, were produced by the effect of decomposition. I afterwards examined fresh human semen, and I then perceived the same bodies. They were in motion, but in the liquid portion; in the thick part they remained immoveable. They were smaller than the corpuscles of the blood, rounded, obtuse before, pointed behind, with a tail five or six times as long as the body." The description of Leeuwenhöek appeared for the first time in the *Philosophical Transactions*, December 1677 and January and February 1678.

In man, and in some animals which approach near to man in their organization, the spermatozoa are small, the head or disc is ovate, the narrow extremity forming the summit of the disc, and the tail, proceeding from its broader end, diminishes in size from its origin to its termination, which is so fine, that its extreme point can with difficulty be discerned. (See Plate XVI. *fig.* 1.)

In the rat and in the mouse the seminal animalcules are large, and their form peculiar; the head is half sagittate, and moveable upon the tail, which is long, and attached not to the base of the arrow-like head, but to its side: frequently the head is curved, in which case it resembles the blade of a curved scimitar. (See Plate XVII.)

In the guinea-pig also, the magnitude of the spermatozoa is great, and the shape remarkable: in this animal the head is large, ovate, concave on one side, and convex on the other, the tapering and elongated cauda arising from the narrow end of the oviform head, which may be compared in form to a mustard-spoon. (See Plate XVII.)

In birds two singular types occur, the one characteristic of the order *Passeres*, the other typical of the *Rapaces*, *Scansores*, *Gallinæ*, *Grallæ*, and *Palmipedes*. In the first, the head of the spermatozoon is elongated and spiral, resembling a corkscrew; the number of coils and the acuteness of the angles vary in different species; usually two, three, or four turns are described; the attenuated and greatly produced tail proceeds from the finer end of the spire, and between it and the body no exact line of demarcation exists. (See Plate XVI. *fig.* 2.) In the second, there is a distinct division into head and tail, and the former is elongated, as in the order *Passeres*; but, in place of being spirally coiled, is straight, the tail arising abruptly from the body, is of great tenuity, of equal diameter, and the length exceeding but little that of the body.

The various forms assumed by the spermatozoa amongst the other vertebrate and invertebrate animals it is unnecessary here to describe: the shape of those, however, belonging to the Tritons and Salamanders, from their great peculiarity, may be briefly noticed. At the junction of the body and tail of each spermatic animalcule an enlargement exists, the excessively attenuated caudal extremity being curved spirally round the body.

The effect of water in modifying the form of the spermatozoa is remarkable, it frequently causing them, when applied in large quantities, to coil up and form themselves into rings: this effect of the application of water is supposed to depend upon some hygroscopic property possessed by the spermatozoa.

Frequently the spermatozoa are seen to occur on the field of the microscope grouped together in bundles, the bodies all lying one way, and fitting by their concavities into each other. (See Plate XVII.) This arrangement, as will be seen hereafter, is connected with the evolution of the spermatozoa.

Occasionally, in man and other animals, the head and tail are separated from each other, and lie apart; this separation is doubtless either the result of violence or the effect of decomposition. Henle * states that he has seen the tail move independently of the head.

Size.

Much diversity exists in the size of the spermatozoa in different animals, although but little difference can be detected in those of the same individual. Wagner, however, has made the observation that their magnitude varies greatly in different individuals of the same species. These variations are, however, of course confined within certain narrow limits. In the Mammalia the spermatozoa of man are amongst the smallest, while those of the guinea-pig and rat are amongst the largest hitherto discovered. In the birds the seminal animalcules of the order *Passeres* are very large, and especially those of the chaffinch.

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* Anat. Gen. p. 534.

Structure.

When first the spermatozoa were discovered and their lively motions observed, much reluctance was entertained to regard them as independent animals or beings; and upon this point, even amongst modern physiologists, there is still an absence of accord, some of them attempting to explain the movements exhibited on purely physical principles.

Not many years ago a celebrated and talented continental observer thus expressed himself in terms more ingenious than accurate in reference to the nature of the spermatozoa: —

"When we place upon the object-glass of the microscope the semen of a subject who enjoys all the energy of his generative faculty, we there see corpuscles more or less rounded or oval, having a sort of caudiform appendix: some have made animalcules of these little bodies, since they have seen that they move, and have believed to have recognised in their movements a determined direction, a character which they thought could only appertain to animated beings. And as amongst the microscopic animalcules which they knew there are those which are provided with a tail more or less prolonged and more or less dilated, they have assimilated to them the little animalcules of the semen, and have made them *Cercariæ.*

"But you are about to see that the conformation and the movements of the corpuscles in question may be explained naturally, without our being obliged to have recourse to the hypothesis of which I have spoken. It is certain that we find in the sperm little gelatiniform masses more or less rounded, oval, and having one part prolonged into the form of a tail, like, in a word, to the drawings which Buffon and many other observers have given us of the pretended spermatic animalcules. These little masses float in a material less consistent than themselves, and even fluid. But at first their oval form results evidently from the manner in which they reflect the light, and afterwards as the fluid in which they are suspended—a fluid which is itself more or less viscous—attaches itself strongly to them, it results that in the micro-chemical movements which take place in the sperm, the corpuscles which it incloses seem to have a tendency to escape from the kind of glutinous material which contains them. This material, seeking, if we may express it thus, to retain them, accompanies them to the situation only where they find themselves to be arrested by a filamentous prolongation, which presents sufficiently well the appearance of a tail, and even of a flexible tail, by reason of the lateral movements which the little body makes in its progression. There is merely in all this, as you see, a mechanical prenomenon, and, in the movement which there takes place, but a physical effect of the contact of two materials of different densities; contact which provokes these materials to mingle together and to form but one, as arrives at the end of a time more or less long. Abandon the semen to itself, taking care that its watery part cannot evaporate by placing it in an atmosphere saturated with humidity, at the end of a certain time the mixture of the two materials will be complete, and you will perceive no longer any thing but a homogeneous fluid; the pretended animalcules have disappeared.

"If we wish to show you at the same time veritable microscopic animalcules and the little gelatiniform masses which move in the vehicle of the sperm, you will find a great difference between the first and these last. I may fortify my opinion on this subject with that of Buffon and Spallanzani, who have denied that the masses of which I speak were animalcules.

"Amongst the persons who have admitted the existence of these beings, there are those who have carried their pretension so far as to class them in genera and species by taking the form of the dilated extremity for the principal zoological character. Some micrographers, also, remarking the differences in the corpuscles of the sperm, according as one procures this liquid from the testicle, the vesiculæ seminales, or after its ejaculation, have pretended, from that circumstance, to describe a series of evolutions in the developement of these so-called *Cercariæ*. They have told us that these animals do not exist in the product which occupies our attention at the moment that it is formed; that they appear but in the vesiculæ seminales; that in these they are as yet but simple globular animals; that in their progress they become developed by the production of their caudal prolongations. Lastly, it has been pretended, — doubtless with the design of marking with ridicule the opinions which we have reported, — it has been pretended, I say, that the spermatic infusorias became amongst us, for example, veritable homuncules, having little arms, little legs, &c. But this is sufficient in itself to put us on our guard against an optical illusion which has unfortunately seduced a great number of persons, from Leeuwenhöek, one of its first favourers, even to MM. Prevost and Dumas, who in these later days have still maintained the existence of the spermatic animalcules."

In the present day, it is needless to enter into any refutation of the above views; it cannot, however, fail to be observed by the reader, that they are weakest just where they should exhibit the most strength, that is, in the explanations given as to the form and motions of the spermatozoa.

Those physiologists who deny the animality of the spermatozoa would, of course, be very reluctant to admit of the existence of any thing like organization in them; while those, on the other hand, who entertained a belief in their animal nature would be most anxious to establish the fact of such organization.

The greatest possible difference of opinion then exists as to whether the spermatozoa are organized or not, and if organized as to the extent to which they are so.

In the centre of the disc of the spermatozoa of man and some other animals a light spot has been observed; this some have imagined to be a stomach; others, again, have rejected this idea, and thus account for its presence: the disc, they say, is not of equal thickness, and, like the red blood corpuscle, is thinnest in the centre, and which part, therefore, exhibits a lighter tint than the remainder: this latter view is most probably the correct one. The first opinion is entertained by Valentin, and the second by Dujardin and Henle. Muller conceived the spot in question to be a nucleus.*

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* Muller's Physiology, p. 635.

Leeuwenhöek remarked upon the spermatozoa of the ram two clear spots; at another time, numerous little points in the interior; a third time, two semilunar striæ, united by a longitudinal line: he figures also in those of the rabbit a multitude of little globules, one of them, larger than the rest, being placed near the tail.

Gerber assigns a most complex structure to the spermatic animalcules of the guinea-pig, describing stomachs similar to those of the polygastric infusoriæ, an anus and sexual apparatus; and, conceiving the existence of these several parts to have been established, he thus expresses himself in reference to the nature of spermatozoa in general: "The compound organization of the seminal animalcules and their production by no equivocal generation, but in particular sexual organs, and by the means of ova, to all appearance proclaim their affinity to the Entozoa."*

Valentin † has described an almost similar amount of organization in the spermatozoa of the bear: "The clear spermatozoa of the bear," he writes, "which in external form approach those of the rabbit, present distinct traces of internal organization, to wit, an anterior and posterior haustellate mouth, and internal cavities or convolutions of an intestine."

Again, Dujardin ‡ has described and figured certain irregular knots and lobular enlargements at the root of the tail of the human spermatozoa; these have been noticed by Wagner, who believes that they occur only as the effects of certain alterations experienced by the animalcules in consequence of their long stay in urine, and especially when this fluid has contained at the same time a quantity of puriform sediment.

Wagner likewise points out, as occurring now and then, but by no means constantly, a small prominence or trunk-like process situated on the anterior part of the body of human spermatozoa: this, or a similar projection, he also states to be much more regularly present in the seminal animalcules of the bat, in which they occur as pointed spines. The same observer has, moreover, noticed upon one or two occasions the caudal end of the body to be double, bifid, or forked, and once too the body appeared to be double, as in a bicephalous monster.*

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* Gerber's General Anatomy, translated by Gulliver, p. 337.

† Repertorium, 1837.

‡ Ann. des Sciences Nat. viii. p. 293. plate 9. 1827.

The above comprise all the particulars which have hitherto been promulgated in reference to the organization of the spermatozoa; scarcely any one of them has however been sufficiently established: we are therefore not authorised to receive them as proved, and to build any reasoning upon them: the most which we are warranted in deducing from them amounts to this, that traces of organization have been discovered in the spermatozoa, the precise nature and extent of which have not as yet been satisfactorily determined.

Notwithstanding his observations given above, Wagner† states that he has been utterly unable, after varied, repeated, and long continued examination, to discover true internal organs in the spermatozoa. Siebold‡ has also been equally unsuccessful in his endeavours to detect such, as also Henle§ and Kœlleker.

The determination of the fact that the spermatozoa are possessed of even the smallest amount of organization, would involve their classification in the animal kingdom, and the description of the different forms which occur as so many distinct species.

The view of the animal nature of the spermatozoa would appear to gather strength, and to admit almost of positive demonstration, by reference to their very remarkable motions.

MOTIONS OF THE SPERMATOZOA.

It is impossible that anything can convey a more just idea of life, than the spectacle of a drop of the seminal fluid in which the spermatozoa are in active and ceaseless motion.

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* Elements of Special Physiology, pp. 10. 16.

† Loc. cit. p. 17.

‡ Siebold in Weigman's Archiv. 1838.

§ Anatomie Generale, t. vii. p. 531.

Sometimes, indeed, when the semen is thick and tenacious, the movements of the contained spermatozoa are but feeble, the density of the liquor seminis presenting too great an impediment to the free motion of these minute creatures.

Often, however, in such cases, when the fluid has been diluted with water or with some other liquid, as serum or milk, of less density than itself, the spermatozoa, being now set at liberty, will frequently be seen to resume their locomotive powers, and to move about with the greatest activity. All the spermatozoa, however, contained in a drop of semen which has undergone dilution will not start into motion at once; many of them will remain for a time perfectly motionless, and then suddenly, and, as it were, by an act of volition, begin to move themselves in all directions.

Mode of Progression.

The motions of the spermatozoa are effected principally by means of the tail, which is moved alternately from side to side, and during progression the head is always in advance.

The strength of the spermatozoa is considerable, it enabling them, when they are immersed in either blood or milk, to cast aside, with the greatest ease, the globules which may present themselves to impede their progress.

The spiral spermatozoa of the *Passeres* advance by a movement of rotation of the body, the tail remaining extended and motionless, acting rather as a rudder than as an organ of locomotion. The spermatozoa of the other orders of birds, and which consist of a cylindrical body to which a short and attenuated tail is attached, "scull themselves forward with their tails, either striking them slowly and with wide sinuosities, or more quickly and shortly, as when a whip is shaken; they thus advance in circles with a quivering motion, holding the body extended in a straight line, although they also now and then bend this in various directions from side to side."*

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* Wagner's Elements, p. 18.

The spermatozoa of the tritons and salamanders usually lie coiled up in the form of a ring, and seem to spin round as upon a pivot; at the same time a second wavy and tremulous motion, like that produced by ciliæ, is observed; this arises from the rapid rotatory or spinning movement of the very delicate tail with which the spermatozoa of these animals are furnished, and which is wound spirally round the body. Wagner at one time entertained the notion, which however he subsequently discarded, that the wavy motion referred to was produced by a ciliary apparatus. Sometimes the coiled spermatozoa have been seen to unrol themselves and to cross the field of the microscope with slow serpentine motions.

Furthermore, in the various motions executed by the spermatozoa they exhibit all the characters of volition; thus they move sometimes quickly, at others slowly, alter their course, stop altogether for a time, and again resume their eccentric movements. These movements it is impossible to explain by reference to any hygroscopic properties which may be inherent in the spermatozoa, they appear to be so purely voluntary. A strong argument, therefore, in favour of the independent animality of the spermatozoa may be derived from a consideration of the nature of their motions.

Duration of Motion.

The length of time during which the motions of the spermatozoa continue, either after the escape of the seminal fluid, or after the death of the animal, varies very considerably; thus it is maintained for a longer period in warm weather than in cold, and when the semen is retained within its natural reservoirs than when it is removed from those receptacles. The spermatozoa of some animals also preserve their powers of locomotion for a longer period than those of others; thus the seminal animalcules of birds die very soon after the death of the bird; according to Wagner, frequently in from fifteen to twenty minutes *; occasionally, nevertheless, the spermatozoa have been found moving in birds which have not been opened until some hours have elapsed after death: those of the Mammalia have been observed in motion for a very long period after the removal of the semen from the testicle, and after the death of the animal; but it is in fishes that the spermatozoa retain their powers of locomotion out of the body for the longest period, even for many days.

According to Dujardin †, the spermatozoa live thirteen hours in the testicles of the mammalia after the death of the animal.

Lamperhoff‡ has found living semen in the vesiculæ seminales of dead men, in which the spermatozoa retained the power of locomotion for twenty hours.

Wagner § has observed them exhibiting motion at the end of twenty-four hours.

Donné ‖ states that he has watched their movements for an entire day, and that he has observed them in motion even on the second day.

It is, above all, in the place of their final destination that the spermatozoa live for the longest period; thus, Leeuwenhoek first, and other observers subsequently, have discovered them in a living condition in the uterus and Fallopian tubes of a bitch seven days after connexion ¶, and Bischoff** has found them alive eight days after intercourse in the rabbit.

The great length of time during which, under certain circumstances, the spermatozoa retain the faculty of locomotion, furnishes another strong argument in favour of their independent vitality.

Effects of Reagents.

The seminal animalcules retain their locomotive powers for a very long time in fluids of a bland nature, for example, in blood, milk, mucus, and pus; on the contrary, in reagents of an opposite character, and in those possessed of poisonous properties, they soon cease to move: thus, in the saliva and urine, unless these fluids be very much diluted, their motions are soon destroyed, and immediately cease in the acids and alkalies, in alcohol, iodine, strichnine, and the watery solution of opium.

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* Wagner, loc. cit. p. 21.

† Annales des Sciences Nat.

‡ Diss. de Vesical. Semin.

§ Loc. cit. p. 22.

‖ Cours de Microscopie, p. 284.

¶ Opera omnia, t. 1. b. p. 150.

** Muller, Archiv. p. 16. 1841.

The addition of water to the spermatic animalcules usually produces a remarkable effect, increasing greatly for a time the rapidity of their motions, which after the lapse of a minute or two entirely cease; this reagent, as well as the saliva, exerts a further peculiar influence upon them, causing them to curl up into circles or rings.

Poisons introduced into the system, and destroying the life, are stated not to affect the motions of the spermatozoa; an assertion to be received with some degree of hesitation: in cases of poisoning by prussic acid, I have usually found the spermatozoa to be motionless even when viewed immediately after death.

The urine has the property of preserving the spermatozoa entire for weeks and months; and Donné has detected them in that fluid after an interval of three months.

The result, then, of the application of reagents, furnishes an additional argument in favour of the animality of the spermatozoa, and one which it would be difficult, if not impossible, satisfactorily to controvert.

SPERMATOPHORI.

The only essential solid elements contained in the seminal fluid arrived at its perfect state, as in the vas deferens, and when ejaculated, are the spermatozoa; occasionally, however, there are encountered in it, as non-essential constituents, mucous corpuscles, epithelial scales, and the seminal granules: the spermatic liquid, however, obtained from the body of the testicle, contains not only the several structures already named, but also minute and bright granules, and the compound cells or spermatophori, the bright granules and the seminal corpuscles probably represent stages in the development of the spermatophori.

The several structures now named are all occasionally met with in the ejaculated semen; their occurrence in it is to be regarded rather as accidental than as essential; the spermatophori belong to the testicle, the tubuli seminiferi of which in many cases are almost filled by them.

The spermatophori differ greatly from each other, both as respects size and the number of secondary cells or nuclei contained within them; the smaller parent cells are about $\frac{1}{1800}$ of an inch in diameter in man, and contain usually but a single nucleus, while the larger ones attain the magnitude of $\frac{1}{800}$ of an inch in breadth, and include not unfrequently as many as six or eight nuclei, or, more properly speaking, secondary cells. Between the two extreme sizes given, every gradation presents itself, and many spermatophori contain but one, two, three, or four nuclei, which are the numbers most frequently encountered.

The secondary cells, like the primary or parent ones, are globular, and those contained within the same parent cell are usually of the same dimensions; the centre of these cells occasionally presents a bright spot. (See Plate XVI. *fig.* 1.)

Not unfrequently certain large and perfectly transparent cells are encountered; these are in all probability the older spermatophori, the contents of which have been discharged.

It would appear, therefore, that the development and dissolution of the spermatophori are effected entirely within the tubes of the testes.

Cells, which Wagner has denominated seminal granules, occur, as already remarked, mixed up with the undoubted spermatophori; these first are smaller, and do not contain nuclei; whether they are really distinct from the latter, it is not easy to determine. If but one kind of cell occurs in the testicle, then a double function must be assigned to it: thus in the first place, the secretion of the liquor seminis must be effected by it; and in the second, the development of the spermatozoa occurs within its cavity; in which case the spermatophori would be the homologues of the cells of other glands, only in so far as they discharge an analogous function, and are secreting organs; in the ulterior office allotted to them, that of being receptacles in which the spermatozoa are evolved, they stand alone in the animal economy, and are certainly without analogues in any other gland of the body.

It is most probable, however, that two kinds of cells co-exist in the testes, the one secreting and corresponding with the cells of other secerning organs; the other kind, of a peculiar nature, without parallel in the animal economy, and devoted to the development of the spermatozoa.

DEVELOPMENT OF THE SPERMATOZOA.

Not the least interesting part of the history of the spermatozoa is that having reference to their development.

Wagner was the first to state that the spermatozoa are developed within the spermatophori just described.

This interesting discovery of Wagner has been amply confirmed by the extended observations of Kœlliker, Siebold, Valentin, and Lallemand.

Wagner thus describes the evolution of the spermatic animalcules in the spermatophori of a bird. "In the course of their development, a fine granular precipitate is observed to form between the included nuclei, by which these are first obscured and then made to disappear, and linear groupings are produced, which anon proclaim themselves as bundles of spermatozoa, already recognizable by slight traces of a spiral formation of one extremity. (See Plate XVI. *fig.* 2. *g.*) It were hard to say whether the fine granular precipitate is to be regarded as the product of a process of resolution occurring to the nuclei, or a new formation; as also, whether the spermatozoa spring out of or only in and amidst the yolk-like matter, or matter that is at all events comparable to the yolk of eggs in general. The vesicles now assume an oval form (see Plate XVI. *fig.* 2. *h*), the globules disappear, the granular contents diminish; the seminal animalcules are well grown and lie bent up within the cyst; their spiral ends are more conspicuous. The delicate covering (involucrum) is now drawn more closely around the bundle of spermatozoa it includes, and where it covers their spiral ends anteriorly it assumes a pyriform outline (see Plate XVI. *fig.* 2. *i*), and at the opposite extremity is perhaps at this time open; but it is difficult to speak decisively on this point. The cysts are now very commonly bent nearly at right angles or like knees, but at length they appear stretched out and straight, and have attained their full size. (See Plate XVI. *fig.* 2. *k.*) The capsules of these vesicles are at all times, and especially towards the end of their existence, highly hygroscopic; the addition of a little water causes them to burst, the masses of spermatozoa rolled up like a little skein of thread or silk escape, and occasionally at this stage exhibit motions individually, which, however, whilst the animalcules continue in the ducts of the testes, are frequently not to be observed, and are never either general or remarkable. The spermatozoa, after the rupture of the cyst, advance in freedom to the vas deferens."*

The process Wagner states subsequently to be precisely similar in man and the Mammalia, although it is more difficult to follow it in them.

The accuracy of the above account of the development of the spermatozoa has been admitted by most other observers in all respects save one important one: thus Kœlliker has shown that the evolution takes place in the included or secondary cells, and not, as Wagner describes it, in the spaces between these, a single spermatic animalcule being formed within each; the granules inclosed in these cells disappear gradually as the spermatozoon assumes a definite form, and Kœlliker further supposes that these granules constitute by their union with each other the substance of the spermatozoa which escape from both the secondary and primary cells by the rupture of their investing membranes. When the spermatic animalcules have escaped from the secondary cells, and these have disappeared, the spermatozoa form a bundle which is still included within the larger primary cell; sometimes the seminal animacules are irregularly disposed within its cavity, but more frequently they are applied directly to each other, the heads lying one way, and the tails in the opposite direction. This disposition of them is often preserved even after their escape from the spermatophori, during their stay in which the spermatozoa usually remain quite motionless.

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* Translation of Wagner's Elements, by Willis, pp. 25, 26.

The interesting and important fact of the development of the spermatozoa in the secondary cells, or ova, as they should now be called, Kœlliker first ascertained by the study of their evolution in the guinea-pig*; subsequently, he extended his observations, and found that the spermatozoa in man were evolved in a manner precisely similar.

Valentin † during his inquiries observed masses of filaments in the mother cells of the rabbit and bear, and Hallman ‡ noticed the same thing in those of the rays; he does not however speak of the transformation of the included nuclei or ova.

In the class of invertebrate animals, it is most probable that a similar method of development prevails.

The spermatozoa are not encountered in equal numbers in all parts of the testicle, the more remote convolutions of the tubuli seminiferi containing chiefly the simple granular cells and the spermatophori, while it is only in those which approach near to the epididymis that they occur in any numbers; in this situation they usually lie immediately beneath the membrane of the seminiferous tube, and external to the spermatophori, their long axes being disposed in the direction of that of the tube itself. In the vas deferens the spermatozoa are present in vast numbers, and with scarcely any admixture of the other solid elements of the testes.

It is in the epididymis that the different stages of development of the seminal animalcules are best seen side by side.

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* Beitrag. p. 56. tab. 11. fig. 20.

† Repert. p. 145. 1837.

‡ Muller, Archiv. p. 471. 1840.

The spring is by far the most suitable period for the study of the development of the spermatozoa, and birds, especially those of the order *Passeres*, present the best examples in which to trace their evolution, because in them the seminal animalcules are large, and the reproductive function is excessively active for a brief and determined period.

Wagner * has shown that from the commencement of the time of moulting, and through the entire winter, the testes of birds undergo an extraordinary degeneration, the spermatozoa and the spermatophori being entirely obliterated, and the volume of the testes reduced to at least the twentieth or thirtieth of the size to which they attain in spring. Thus the testis of the common chaffinch is in winter not larger than a millet seed, while in spring it exceeds a pea in size.

The same degeneration is doubtless experienced during winter, although to a less extent, by most animals of the class Mammalia.

THE SPERMATOZOA ESSENTIAL TO FERTILITY.

The spermatozoa do not exist in the testes of mammalia at all periods of life: thus they do not make their appearance in that organ in man until the period of puberty, and they disappear gradually as old age advances. It is impossible however to determine the time at which they are first developed, or at which they cease to exist in that organ, because the period of puberty differs in different individuals, and some men are aged in constitution when others of the same years are hale and robust. Certain it is, that some men retain the power of engendering until a very advanced age, of which fact the celebrated Parr presents a memorable example, he having become a father at the extraordinary age of 142.

The number also of the spermatozoa contained in the seminal fluid varies in different individuals, and is usually in proportion to the activity of the reproductive function, and this again is dependent to a great extent upon the constitutional powers as well as upon the mode of life.

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* Elements, pp. 28. and 29.

The activity then of the reproductive faculty in man is in many cases a good test of health.

The above few facts favour the idea of the essentiality of the spermatozoa; others however, of a stronger kind, still remain to be mentioned.

Wagner has instituted some most interesting inquiries in reference to the condition of the spermatozoa in male hybrids, and especially in male hybrid birds, and he finds, that in them the characteristic animalcules are either altogether wanting, or occur but in small numbers, and are ill-formed and ill-conditioned; the hybrids in which the seminal animalcules have been thus found to be absent or degenerated, have been ascertained to be incapable of having offspring.[*]

Again, Leeuwenhoek[†] discovered living seminal animalcules in the uterus and Fallopian tubes of bitches seven days after connexion.[‡]

Prevost and Dumas[§] have more recently made the same observations at the same length of time after intercourse.

Siebold[‖] has detected the spermatozoa in a living state in the uterus and Fallopian tubes eight days after connexion.

Lastly, Bischoff[¶] and Martin Barry[**] have observed the spermatozoa not merely in the uterus and Fallopian tubes, but also on the ovary itself.

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[*] Loc. cit. pp. 30—34.

[†] Opera omnia, p. 150.

[‡] Leeuwenhoek signalised the discovery of the living spermatozoa in the uterus and Fallopian tubes, in the following words:—"Nudo conspiciens oculo, nullum masculum semen canis in ea esse dicere debuissem; at eandem mediante bono microscopio, summæ meæ voluptati immensam viventium animalculorum multitudinem; semen nempe canis masculum contemplabar. His peractis, dictam aperiebam tubam, in fine suæ crassitudinis, ac ibidem quoque magnam seminis masculi canis contemplabar copiam, quod semen illic vivebat, et hoc modo quoque cum dextra egi tuba, ac in eadem quoque immensam seminis viventis canis masculi copiam observavi. . . . Materiam qua matrix concita est, observans majorem adhuc viventium animalculorum copiam deprehendebam."

[§] Annales des Scien. Nat. t. iii. p. 122.

[‖] Müller, Archiv. p. 16. 1841.

[¶] Wagner's Elements, p. 66.

[**] Researches in Embryology, Second Series, Phil. Trans. p. 315. 1839.

From these facts it is therefore evident that the spermatozoa are essential to fecundity, although the precise manner in which they are so is still involved in the greatest obscurity. It is supposed by some observers, that they make their way into the ovum itself: this notion is as yet without evidence to support it.

It would be most interesting to determine whether impregnation could be procured by the artificial introduction of semen, the animalcules of which were dead; there is every reason to believe that in the many cases in which the artificial injection of the seminal fluid has been successful, the contained spermatozoa were in a living condition; and from all that is yet known in relation to the animalcules, there is strong presumption to believe that the experiment referred to, viz. the introduction of semen, the animalcules of which were dead, would be unattended with success.

One remarkable experiment of Spallanzoni, however, deserves to be referred to. Most observers agree in saying, that the spermatozoa of the frog die after some hours of immersion in water. It is known, however, that Spallanzoni succeeded in fertilising the ova of frogs with spermatised water, containing three grains of seminal fluid to eighteen ounces of water, thirty-five hours after the mixture had been prepared, and this, in a chamber with the thermometer at from 17 to 19 degrees; and again, that in an ice-house, the thermometer being three degrees above zero, the spermatised water preserved its prolific power for fifty-seven hours.

Now, the tendency of this interesting experiment is certainly to prove the possibility of fertilisation occurring with semen, the spermatozoa of which are dead: this inference would appear however to be negatived by another ingenious experiment of MM. Prevost and Dumas, who filtered the seminal fluid and found that the fluid portion which passed through the filter would not vivify the eggs, while the more solid part, consisting of the spermatozoa, produced the results peculiar to the seminal fluid.

Jacobi succeeded in fertilising the ova of a carp with semen which had been contained within the body of the fish for four days; but it is well ascertained that the spermatozoa of fishes in general live for a much longer period than that named.* Some have supposed that the only use of the spermatozoa is by their movements to hasten the advance of the semen towards the Fallopian tubes.

PATHOLOGY OF THE SEMINAL FLUID.

The quantity of seminal fluid secreted varies greatly according to the age and constitution of the individual. In young men, and in those whose health is vigorous, the secretion is rapid and abundant; in the aged, and in those whose vital powers are feeble, it is but slow and scanty. It is, however, in severe states of disease that the amount of seminal fluid secreted is greatly diminished, if the formation of it be not in some cases altogether suspended for a time. Under the influence of recovery, the quantity of semen formed again undergoes an augmentation.

An inordinate secretion of the seminal fluid, as also its prolonged retention in the testes, are sometimes the causes of involuntary seminal discharges, which, however, are more frequently occasioned by organic weakness, the result of over indulgence.

If these emissions be very frequent, the ejaculated semen will be found to be thin and watery, and to contain comparatively few spermatozoa.

It is unnecessary to describe here the destructive effects of these emissions on the constitution.

It is often a matter of great importance to determine, independently of any revelation on the part of the patient, whether in any particular case seminal effusions exist.

This fact, it is in the power of the microscope, according to some observers, in all cases to declare with the most absolute certainty.

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* Several most interesting particulars in reference to artificial impregnation are given in Wagner's Elements, chap. iii.

After each effusion of semen, in whatever way occasioned, a certain amount of that fluid will still remain behind, adhering to the surfaces of the urethra; this, of course, contains the seminal animalcules, which will be washed away on the first passage of the urine through the urethra.

The great object, then, is to establish the fact of the existence of spermatozoa in the urine: this may be accomplished in two ways; either by filtration or decantation, the latter being perhaps the preferable method of the two; the spermatozoa, being heavier than the urine itself, always subside at the bottom of the vessel, and where they may always be found, if present in even the smallest numbers.

The urine, as already mentioned, has the property of preserving the seminal animalcules, which may be detected in it months after their discharge from the urethra.

M. Donné * states, that he has never succeeded in detecting the seminal animalcules in the urine, unless as the consequence of an emission of semen, and which may have occurred either during connexion, in an involuntary manner, or through masturbation. Now, if this be true, the occurrence of the spermatozoa in the urine declares positively the fact, that a discharge of semen has been sustained, and this particular is often in itself sufficient to enable a medical man to form an opinion of the case.

It seems to me, however, by no means sufficiently proved, that an escape of the seminal fluid with the urine does not take place independently of any distinct emission. I am inclined to think that such escape is an habitual occurrence even with the most healthy, especially with the continent, and that by it the surcharged testes are relieved whenever requiring such relief.

This view is to some extent supported by the observations of Dr. John Davy † and Wagner ‡: the former excellent observer states that on examining the fluid from the ure-

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* Cours de Microscopie, p. 318.

† Edin. Med. Surg. Jour. vol. ii. p. 50.

‡ Loc. cit. p. 21.

hra after stool in a healthy man, he had always detected permatozoa.

In connexion with the above few remarks on the pathology of the semen, we may refer to the observations of Donné on the effects of an exceedingly acid condition of the mucus of the vagina, and a very alkaline state of that of the uterus itself, on the vitality of the spermatozoa.

The mucus of the vagina, in its normal state, is slightly acid, this degree of acidity being perfectly compatible with the life of the seminal animalcules; but Donné has shown that under some circumstances, as from congestion, irritation, or inflammation, this mucus becomes so strongly acid as to destroy in a few seconds the vitality of the spermatozoa.

Again, the mucus of the uterus in its healthy state is slightly alkaline, but not so much so as to exert any injurious effects upon the spermatozoa; in conditions of derangement and disease, however, it becomes so alkaline, as Donné has shown *, that in like manner with the acid mucus of the vagina, it kills the seminal animalcules in a very short space of time.

Now after what has been said and detailed in reference to the essentiality of the spermatozoa, it can scarcely be doubted that women whose vaginal and uterine secretions are so disordered, are inapt to conceive, and this from the effect of their vitiated secretions upon the spermatozoa.

It would be interesting to determine whether the spermatozoa are ever entirely absent from the semen of man: it is very probable that in certain rare cases they are so, and from the facts already ascertained there can be no doubt that those individuals whose spermatic fluid is devoid of its characteristic living element would be wholly incapable of having offspring.

It is probable, that in the impotent the spermatozoa are almost, if not entirely, extinct.

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* Cours de Microscopie, p. 292.

APPLICATIONS OF A MICROSCOPIC EXAMINATION OF THE SEMEN TO LEGAL MEDICINE.

The detection of the spermatic animalcules is frequently a matter of high interest and importance in a medico-legal point of view.

There are three classes of cases in which the microscope, by revealing the presence of spermatozoa, is capable of forwarding the ends of justice and of bringing conviction home to the guilty.

1st. In cases of suspected violation.

2nd. In determining the nature of doubtful stains observed on the bed-clothes, &c.

3rd. In unnatural offences.

With respect to those cases which come under the first division, it may be observed that the medical testimony on which these are usually decided is too often of such a nature as to lead to the acquittal of a really guilty individual; the medical man, judging merely from external appearances, being compelled to give evidence either directly favourable to the prisoner, or which is at best but of a doubtful character.

In suspected violation, then, when the evidence to be deduced from an outward examination is insufficient for the formation of a satisfactory and decided opinion, the microscope may frequently be employed with the greatest advantage.

If the offence imputed has been committed, and if connexion has really occurred, then by means of this instrument, provided too long a time has not elapsed from the period of the occurrence, that is to say, a period not exceeding from twenty-four to forty-eight hours, the spermatozoa will be detected in the mucus, properly examined, and obtained from the upper part of the vagina: now the detection of these in such a situation is a demonstration that intercourse has taken place.*

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* Donné, in the Cours de Microscopie, states that he has detected the spermatozoa in the vaginal mucus of women admitted into the hospital,

The examination of the urine of women whose persons are suspected to have been violated would also frequently furnish evidence of the fact by manifesting the presence in it of the spermatozoa, which in its passage through the vagina it had washed away from its walls.

With reference to the second class of cases mentioned, those requiring for their satisfactory elucidation the determination of the nature of suspicious stains, here again, by means of the microscope, evidence the most conclusive may frequently be obtained.

Now, if the stains in question be formed by the seminal fluid, and if they be not too old, the microscope applied to them will detect in them the spermatozoa.

With regard to the length of time at which the spermatozoa may be detected in the matter of a stain, I have reason to think that this has scarcely a limit: I have myself noticed them in the semen several weeks old, and they then appeared to have undergone scarcely a single appreciable change, the spermatophori contained in the seminal fluid being equally well seen.

In examining stains occasioned by the seminal fluid, it is advisable to use the same precautions as those which were pointed out in reference to blood stains, and to moisten them with either serum or albumen.

The reader's imagination will suggest to him numberless cases in which the determination of the nature of suspected stains would be a matter of the utmost importance, and would lead to the production of evidence of the greatest consequence, and in no other way obtainable.

Lastly, with reference to the third class of cases, those of unnatural offences: here also the microscope, by revealing the presence of the spermatozoa in the rectum, or on some other part of the body, may throw great light on occurrences which otherwise would in all probability be buried in complete oblivion and mystery.

in which instances it is most probable that connexion had occurred at least some hours previous to admission.

An examination of this kind was assigned by the magistrates in France some years ago to two physicians, on the occasion of an assassination in an hotel. A traveller having been killed by a young man whom he had received into his chamber during the night, justice was interested to know whether semen would be found in the rectum or not.*

It is known that in death by hanging, an emission of the semen usually occurs, and this, in the absence of other proofs, has been adduced as a sign of death by suspension. It would appear, however, that such an indication is not without its sources of fallacy.

It is thus apparent that in the cases here referred to, the microscope is capable of affording *positive* evidence of a most important and conclusive kind; on the other hand, the *negative* testimony deducible from its application in these cases is not without its value.

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* See Annales d'Hygiène Publique et de Médecine Légale, Paris, 1839, t. xxi. pp. 168. and 466.

UNORGANISED FLUIDS.

Art. VII. SALIVA. — BILE. — SWEAT. — URINE.

The fluids comprised under the heading of Unorganised Fluids differ from those of the first division, viz. the Organised, in that they do not contain, as essential elements, organised structures; solid organic particles are indeed usually to be encountered in them, but these are to be regarded either as accidental or at all events as non-essential adjuncts, and which appertain usually to the structure of those organs from which the fluids have themselves proceeded.

The presence and nature of the solids contained in the Unorganised Fluids serve to indicate to a considerable extent the condition of the glands by which they have been secreted, and thus frequently throw great light upon their pathology.

There is, however, one kind of solid constituent which is found almost constantly in these fluids, viz. the crystals of various salts: these being however unorganised, their consideration does not properly belong to a work devoted to descriptions and delineations of organised tissues.

It is proposed, therefore, in order to render the application of the microscope to human physiology and pathology as complete as possible, to prepare a separate treatise on the subject of the crystallisations formed in the various fluids, &c. of the body, under the title of Human Crystallography.

We will now pass in review the fluids comprehended in the division of Unorganised Fluids. In reference to some of them but little remains to be said, as will have been inferred from a knowledge of their structureless character. In the treatise on Crystallography, however, many interesting and important details will be given.

The Unorganised Fluids comprise the *saliva*, the *bile*, the *sweat*, the *urine*, and the *gastric*, *pancreatic*, and *lacrymal* fluids; these several fluids especially deserve the name of secretions, since they are elaborated by large and complexly organised glands.

THE SALIVA.

The saliva is a peculiar fluid secreted by the parotid, submaxillary and sublingual glands, from which it is conveyed by certain ducts into the mouth, where it becomes mingled with the buccal mucus. The amount of saliva secreted during the day is estimated at from ten to twelve ounces; during salivation either spontaneous, or induced by mercury, the quantity may exceed two or three quarts. It is worthy of remark, however, that in these latter cases the mercury has never been detected in the saliva.

Mitscherlich * made the following observations on a person having a salivary fistula, and in whom the saliva could be collected directly as it flowed from Steno's duct. He found that there was no flow of saliva while the muscles of mastication and of the tongue were in complete repose, and all nervous excitement avoided. He observed also, that during the acts of eating and drinking, especially at the commencement, the secretion was most abundant, and in proportion to the stimulating nature of the food and the degree to which it was masticated. From two to three ounces of saliva flowed from the duct in the course of twenty-four hours.

The solid constituents of the saliva are composed of fat, ptyalin, watery and spirituous extractive matters, a little albumen, certain salts, a trace of sulphocyanogen, mucous corpuscles, epithelial scales, and lastly, corpuscles resembling mucous globules, which have been termed salivary corpuscles, and which are probably nothing more than epithelial cells in progress of development.

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* Rust's Magaz., vol. xl.

The salts of human saliva are, according to Mitscherlich, chloride of calcium, lactates of soda and potash, soda either free or combined with mucus, phosphate of lime, and silica.

In certain pathological states Simon detected in the saliva acetic acid, and a considerable quantity of a substance resembling casein.

The saliva is with difficulty to be obtained in a pure state, it being generally intermixed with a greater or less quantity of buccal mucus; now the normal reaction of the saliva is alkaline, that of mucus acid; it therefore follows, the fluids in question being thus intermingled in variable proportions, that the reaction presented by the fluid obtained varies according to the relative quantity of each ingredient; thus sometimes the saliva, when tested, will appear to be acid, alkaline, or neuter, and the same will be the case with the buccal mucus.

The true reaction of the saliva, then, can be ascertained only by obtaining it unmixed with the mucus of the mouth, and then testing it; this may be effected by first washing the mouth with water, and then applying the test paper to the saliva as it flows from the orifice of its ducts.

The fact referred to of the admixture of the two fluids, saliva and mucus, will serve to explain why test paper applied to the upper surface of the tongue exhibits frequently an acid reaction, while that placed beneath it manifests the presence of an alkaline fluid.

In morbid states the normal reaction of the saliva may undergo a complete change, and it may become either neuter or acid: this alteration has been especially observed to occur in deranged conditions of the stomach, in acute rheumatism, in cases of salivation, and, according to Donné, in pleuritis, encephalitis, intermittent fevers, uterine affections, and amenorrhea.

Acid saliva doubtless exerts a very injurious effect upon the teeth.

The admixture of the saliva with mucus is readily shown by means of the microscope, which reveals the presence of mucous epithelial scales in all stages of their development; as the scales found in the sweat are derived from the desquamation of the epidermis, so are those of the saliva and mucus from that of the epithelium.

The saliva as well as the sweat yields on evaporation crystals of the various salts referred to in the analysis.

Blood corpuscles are sometimes present in the saliva and mucus; these proceed usually from the gums.

The uses of the saliva in the animal economy are classified by Dr. Wright as follow: —

Active. 1. To stimulate the stomach and excite it to activity by contact. 2. To aid the digestion of food by a specific action upon the food itself. 3. To neutralise any undue acidity of the stomach by supplying a proportionate alkali.

Passive. 1. To assist the sense of taste. 2. To favour the expression of the voice. 3. To clear the mucous membrane of the mouth, and to moderate thirst.

THE BILE.

The bile, like the unorganised fluid already described, presents but little of interest to the microscopist in its normal state.

It happens, however, occasionally, when it has been retained in the gall-bladder for a long time, in consequence of which it has become inspissated, that it does contain solid and coloured particles.

These particles have been noticed by Scherer* and also by Dr. H. Letheby of the London Hospital, who was so considerate as to transmit, for my examination, a portion of inspissated bile, containing them, as also plates of cholesterine, in great numbers.

The bodies in question consist of two parts, an external colourless investing portion, and an internal coloured and granular matter; this disposition of the colouring matter imparts to them the aspect of "pigment cells," which, in fact, Scherer considers them to be.

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* Untersuchungen, &c., p. 103.

There are but three kinds of cells, which, if cells at all, they could be by any possibility, viz. liver, epithelial, or pigment cells; now, they are certainly neither of the first two mentioned, as may be inferred from the dissimilarity of size, appearance, and structure with these; and they are as surely not "pigment cells," because such structures do not enter into the organisation of the liver.

It is then conceived, that these cell-like bodies are not true cells, but are to be regarded as masses of concrete mucus enclosing more or less biliary colouring matter; the great differences observed in their form, size, and general appearance are all opposed to the notion of their being definitely organised cells.

The meconium of infants very generally contains the cell-like bodies described, together with intestinal mucus, cuneiform epithelium, and occasionally cholesterine in a crystalline form.

THE SWEAT.

The sudoriparous glands, distributed over the whole surface of the body, constantly secrete a very considerable quantity of watery fluid: this fluid passes off usually in the form of an insensible vapour; in some cases, however, as under high external temperature, active exercise, and in certain stages and forms of disease, it collects on the skin in the form of drops, which, in drying up, deposit their solid constituents over the whole extent of the cutaneous surface: it is then more particularly termed sweat.

Many attempts have been made to determine the amount of fluid passing off by the skin; the average quantity, according to Seguin, amounts to about twenty-nine ounces of fluid, the maximum to five pounds, and the minimum to one pound, eleven ounces, and four drachms.

The amount of solid constituents carried off with the fluid is, comparatively, very small, not exceeding in the twenty-four hours seven or eight scruples; the remainder being merely water, retaining in it carbonic acid and nitrogen, the quantity of the former gas being increased by vegetable diet, and the amount of the latter by an animal regimen.

Simon has established the existence, in normal sweat, of—

1. Substances soluble in ether: traces of fat, sometimes including butyric acid.

2. Substances soluble in alcohol: alcohol extract, free lactic or acetic acid, chloride of sodium, lactates, and acetates of potash and soda, lactate or hydrochlorate of ammonia.

3. Substances soluble in water: water extract, phosphate of lime, and occasionally an alkaline sulphate.

4. Substances insoluble in water: desquamated epithelium, and after the removal of the free lactic acid by alcohol, phosphate of lime with a little peroxide of iron.

The quantity of fluid exhaled is subject to very great variations; thus it is increased by a dry and light atmosphere, while it is diminished by a damp and dense condition of the air. It is at its minimum at and immediately after meals, while it is at its maximum during the actual period of digestion. The cutaneous perspiration is in antagonism with the urinary secretion; thus an excessive secretion of urine diminishes that of the skin, and a diminution of the activity of the kidneys is usually followed by an augmentation of that of the sudoriparous glands.

But little of interest, in a microscopic point of view, attaches to this fluid; the only solid organic constituent contained in it being detached scales of epidermis, which is ever undergoing a process of destruction and renewal; these scales, therefore, do not form part of the sweat, but become mixed up with it in a secondary manner.

The copious formation and discharge of the cutaneous fluid which occur under certain circumstances, thus do not merely afford a relief to internal organs, but serve also, by detaching and washing away the older and useless cells, to cleanse the epidermis, and to render this more efficient as an evaporating surface.

The crystals formed on the evaporation of the sweat, in states of health and disease, have been but little studied; it is probable that a knowledge of them would lead to the discovery of some facts of interest.

The cutaneous fluid, it is known, is in health acid; there are some situations, however, in which it is constantly alkaline, as in the axillæ, about the genital organs, and between the toes; this, probably, arises from its admixture with the secretions of the small follicles which are situated in those parts.

The sweat, like the urine, is to be regarded as a cleansing fluid, the system being through it relieved of certain surplus and effete matters.

The pathology of the sweat is but little known: albumen has been observed in it by Anselmino, in a case of *febris rheumatica,* and Stark states, that it may be met with in the sweat in gastric, putrid, and hectic diseases, and also on the approach of death. The amount of acetic acid, ammonia, and the salts, may all be increased. Uric acid and quinine have been found in the sweat, the latter preparation being of course at the time administered medicinally.

THE URINE.

Few fluids have been more studied of late years by the microscopist than the urine; this has arisen from the elegance of form, variety of composition, and important character of the numerous crystalline deposits which are formed in it in states of health and disease, and which can be satisfactorily determined only by the aid of the microscope.

The great advantage of the application of the microscope over that of chemical tests to the study of the urine is, that the indications which it affords are not merely certain, but also prompt and facile, while the results obtained through the agency of chemistry, although not less certain, are often tedious and difficult.

The description of the various crystals formed in the urine is reserved for another occasion; in this place will be noticed only the organic constituents which occur in normal and abnormal urine.

In order that the pathological alterations to which the urine is liable may be more clearly understood, it will be advisable, first, to describe the appearance and the constitution of healthy urine.

Healthy urine, when first passed, is a limpid fluid of an amber colour, emitting a peculiar odour, exhibiting an acid reaction, and having a specific gravity of about 1011.

Abandoned to itself, it soon loses its limpidity, becomes troubled, and putrifies more or less quickly, according to its chemical constitution, and the state of the temperature.

The following is Berzelius' analysis of healthy urine, and with which all other subsequent analyses have been found to agree to a very considerable extent: 1000 parts contained,—

Water	933·00	
Solid residue	67·00	
Urea	30·10	
Uric acid	1·00	
Free lactic acid, lactate of ammonia, alcohol, and water extract	17·14	
Mucus	0·32	
Sulphate of potash	3·71	Fixed salts, 15·29.
Sulphate of soda	3·16	
Phosphate of soda	2·94	
Biphosphate of ammonia	1·65	
Chloride of sodium	4·45	
Chloride of ammonium	1·50	
Phosphate of lime and magnesia	1·00	
Silicic acid	0·03	

It will be seen from the above analysis that healthy urine does not contain the nitrogenised principles albumen, fibrin, or casein, which are encountered so frequently in urine voided in disease.

The only solid organised constituents which are constantly encountered in healthy urine, are mucous corpuscles and epithelial scales; these do not form part of the urine, but belong to the structure of the mucous membrane of the bladder and urethra, and both of them may be detected with the greatest facility by the microscope. On account of their greater specific gravity, they subside at the bottom of the vessel containing the urine, where they may, at most times, be procured for examination.

Occasionally, however, in the urine of man, under the circumstance already referred to in the article on the semen, the spermatozoa are present in the urine also.

PATHOLOGY OF THE URINE.

The organic principles contained in diseased urine may be divided, firstly, into those which are usually encountered in that fluid in a state of solution, but which do yet, under certain circumstances, assume the solid form; and secondly, into those which being definite organisms, occur only in a solid condition. Albumen, fibrin, casein, and fat, belong to the first, and the blood and pus corpuscles to the second division.

Albuminous Urine.

Albumen is frequently present in the urine in disease; it has been noticed to occur especially in Bright's disease of the kidney, and in the urine passed after scarlatina.

If the albumen be present in any considerable quantity, nitric acid or bichloride of mercury will cause a precipitate, and the urine will become turbid on the application of heat, and deposit flocculi of coagulated albumen.

The colour, specific gravity, and reaction of albuminous urine are various; thus it may be either light or dark coloured, it may be of high or low specific gravity, it may exhibit either an acid or an alkaline reaction, or it may be neutral.

When the albumen is small in quantity, heat is the most efficient test for its detection; it is only when the urine manifests a decided alkaline reaction, that nitric acid is preferable, the albumen being held in solution by the free alkalies.

Urine may, however, become turbid from the application of heat, even when no albumen is present: this arises from precipitation of the earthy carbonates; in these instances, the addition of nitric acid will immediately disperse the cloudiness, and the reapplication of heat will not occasion any further precipitation.

Dr. G. O. Rees has observed that the urine of persons who have been taking cubebs or balsam of copaiba is rendered turbid by nitric acid, although it contains no albumen: this urine, however, is not affected by heat.

From the facts contained in the two preceding paragraphs, it follows that a precipitate might possibly ensue on the application of heat, and by the addition of nitric acid, and yet no albumen be present in the urine.

If the precipitate yielded by nitric acid, added to urine impregnated with the active principles of cubebs or copaiba, be examined with the microscope, it will be found to consist of minute oil bubbles, which are of course readily soluble in ether.

Fibrinous Urine.

Fibrin has been encountered in the urine independently of the other constituents of the blood: Zimmerman * has described seven cases of fibrinous urine.

Such urine, if the fibrin existed in it in any quantity, would coagulate or form a clot.

It is necessary in these cases not to confound mucus with fibrin; the former, under the microscope, exhibits the well-known mucous corpuscles, while the latter appears either filamentous or simply granular.

Fatty Urine.

The urine may contain fat, either separately or conjointly with albumen, or with casein, and probably also sugar: the urine holding fat in a free state may be called *fatty;* that in combination with albumen *chylous;* and lastly, the urine in which fat occurs in connexion with casein and sugar may be denominated *milky* urine.

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* Zur Analysis und Sunthesis der pseudoplastischen Prozesse, Berlin, 1844. p. 129.

Fatty urine has been observed to occur frequently in persons labouring under phthisis; the fat, as the liquid cools, forming a thin pellicle on its surface, the nature of which may be at once ascertained by the microscope, which, if it be really fatty, will reveal the presence of innumerable fat globules.

Cases have been recorded in which the quantity of fat has been so considerable that it could be detected with the naked eye.

Chylous Urine.

Chylous urine is a white semi-opaque fluid, and contains both fat and albumen; the former may be detected by means of the microscope, and the latter will be coagulated by heat, by nitric acid, and the bichloride of mercury. Examined microscopically, the coagulated albumen exhibits a granular texture.

This form of urine has been observed principally in cases of gout.

Milky Urine.

True milky urine is of very rare occurrence, there being but two or three well-authenticated cases of it recorded; urine containing the constituents of chyle having doubtless been described, in many instances, as milky urine.

The fat in milky urine occurs in combination with casein, and probably with sugar also.

The fatty constituent may be detected as in the previously described urines, the fatty and the chylous, by means of the microscope, and the casein will be precipitated by the addition of a little acetic, dilute sulphuric, or hydrochloric acid, the flocculi of which, examined microscopically, will exhibit a granular, and even in many cases a globular constitution; they will contain also a greater or less number of fat globules.

Urine containing casein in solution may be distinguished from albuminous urine by the application of heat, which in the latter will occasion a precipitate, none being formed in the former, unless indeed a considerable quantity of nitric acid be also present in the urine, when a temperature of 104 Fah. will be sufficient to occasion the precipitation of the casein.

It is not to be supposed by the use of the term milky urine, that the milk, as such, ever exists in the urine, and that it finds its way there from the mammary gland by metastasis; the utmost that is to be inferred from the existence of the principal elements of milk in the urine is, that the kidney, in place of the mammary gland, has separated those elements from the blood.

Excess of Mucus in the Urine.

In *catarrhus vesicæ*, an affection to which old persons are particularly liable, mucus is secreted in considerable quantities, and is voided with the urine.

This mucus subsides to the bottom of the vessel, is semi-opaque, thick, and ropy; examined with the microscope, mucous corpuscles and epithelial scales are encountered in it.

In those cases in which the urine is very alkaline, the mucus is observed to be particularly tenacious and thready: this condition results from the action of the free alkalies contained in the urine upon the constitution of the mucus.

Blood in the Urine.

Blood is frequently contained in the urine and voided with it; thus it is frequently encountered, in greater or less quantity, in the following cases, —in inflammation of the kidneys, in injuries of those organs, or of the bladder itself, in cases of stricture from the introduction of a catheter, from the passage of renal or urinary calculi, and lastly, from chronic disease of the kidneys and bladder.

The best test of the existence of the blood in the urine is the detection of the blood corpuscles by the microscope; blood, however, may exist in the urine, and yet no corpuscles be detected, these having been dissolved by the acids of the urine. Failing, however, to detect the blood discs, if blood really be present, then the albumen, fibrin, and hematin will still remain, and may be distinguished by suitable reagents.

From the colour of urine no conclusion can be formed as to the existence of blood in it, as urine of a deep blood colour is sometimes met with, which on examination is found not to contain any trace of blood.

Pus in the Urine.

It has already been stated in these pages that no absolute distinction exists between mucus and pus; and, therefore, it follows that it is in most cases impossible to determine, with any degree of certainty, whether pus exists in the urine or not.

If, however, the sediment rendered with the urine want the tenacity of vesical mucus, and contain the granular corpuscles common to mucus and pus, there is reason to suspect that the fluid in question is really purulent.

The diagnosis will however be greatly assisted by reference to the history and symptoms of the case; thus if there be rigors and hectic fever, the probability of the existence of pus will be much strengthened.

There is one circumstance which requires to be mentioned, and which greatly increases the difficulty of discrimination between mucus and pus. In some cases of purulent urinary deposits the urine is alkaline; now the effect of the action of alkalies on pus is to convert it into a transparent and tenacious substance in every respect resembling mucus, and which therefore cannot be distinguished from it.

There are but few details interesting to the microscopist connected with the *Gastric*, the *Pancreatic* and the *Lacrymal* fluids; it will therefore be unnecessary to treat of them at any length. It is to the chemist and physiologist chiefly that the gastric fluid is interesting. They all, however, but especially the gastric and the lacrymal secretions, contain mucous corpuscles and epithelial scales, derived from the desquamation of the epithelium of the surfaces by which they are secreted, and over which they pass.

Obs.—At page 144. the opinion is attributed to Mr. Addison, that the white corpuscles of blood, mucus, and pus contain filaments, whereas it would appear from a closer examination of the text, that the statement of that gentleman only goes to the extent of asserting, that the fluid inclosed in those corpuscles resolves itself in its escape into the filaments, of which the brinous portions of blood, mucus, and pus are under certain circumstances observed to be constituted.

PART II. THE SOLIDS.

THE division of the various constituents of the animal fabric into the two orders of FLUIDS and SOLIDS, although a very ancient one, is yet, to a certain extent, arbitrary and artificial. The truth of this observation is rendered apparent on reference to the several fluids, the description of which has just been brought to a conclusion, and all of which contain suspended in them, either as essential or as accessory elements, various solid and organised particles: the liquid portion of some of these compound fluids exhibiting also a distinctly organised constitution, as, for example, the liquor sanguinis and the fluid parts of mucus and of pus.

The distinction referred to is not however without its use, and is sufficiently well founded to serve the purposes of classification.

Of the SOLIDS themselves it is unnecessary to make any formal subdivisions: they will simply be treated of in the order of their natural relationship with each other.

Thus the various solid structures entering into the constitution of the animal organism will be described consecutively as follows, each forming the subject of a distinct article: *Fat, Epithelium, Epidermis, Pigment Cells, Nails, Hair, Cartilage, Bone*, and *Teeth;* the various *Tissues*, the *Cellular*, under which head *Ligaments* and *Tendons* will be described, the *Elastic*, the *Muscular*, and the *Nervous*, including the description of the *Brain* and *Nerves;* the *Glands, Vessels, Membranes;* and, lastly, the *Pathology of the Solids*, will be treated of.

Art. VIII. FAT.

The transition from the fluids to the solids would appear to be a very easy and natural one through the substance about to be described: thus fat bears an evident relation to both the former and the latter, remaining during life in a soft and semi-fluid state, and after death becoming hard and solid; it is, however, to the milk globules amongst the fluids that it manifests the closest affinity, the fat vesicles, especially those of early life, and the milk globules resembling each other in form, in appearance, and in the manner in which re-agents act upon them.

Fat is made up of the aggregation of a number of globules or vesicles, which some deem to be true cells, and which are held in juxta-position by intersecting bands of cellular tissue; these vesicles have a smooth surface, semi-opaque texture, and they reflect the light in the strongest manner.

Contents. — The contents of fat vesicles usually present a homogeneous appearance, sometimes nevertheless, as when undergoing decomposition, and when they have been subjected to pressure, they exhibit a granular aspect; these contents are of an oily nature, and chemists have detected in the lard of the pig the organic products, oleaine, stearine, margaric acid, a yellow colouring matter having the odour and the nauseous taste of bile, and the chemical salts, chloride of sodium, acetate of soda, and traces of carbonate of lime and oxide of iron. It is probable that of these constituents the presence of the chloride of sodium depended on the mode of preparation of the lard.

Form. — The form presented by the fat vesicles is various, but is usually either globular, oval, or polygonal. The first shape is encountered in the fat of young animals especially (see Plate XVIII. *fig.* 1.); the second in that of adults (see *fig.* 2.); and the third in situations where the fat is subjected to considerable pressure and on solidification after death. The fat vesicles of the pig are described as being elongated and kidney-shaped. This shape, however, is of rare occurrence, and cannot be regarded as the ordinary and characteristic form, which is most generally more or less spherical or oval. Raspail, observing this exceptional form, was led to institute from it an erroneous comparison between fat vesicles in general and the starch granule.

Size. — The fat vesicles of the adult are usually several times larger than the solid corpuscles of any of the fluids described, the blood, mucus, and milk: the size of the fat vesicles in any given quantity of fat is not uniform; but, like the globules of milk, varies exceedingly, the dimensions of the larger vesicles surpassing several times those of the smaller.

One exceedingly interesting law has been observed in reference to the size of fat vesicles; thus it has been ascertained that their average magnitude increases from infancy up to adult age: in accordance with this law the fat cells of an infant will be found to be several times smaller than those of a full-grown person, and those of a child again of an intermediate size. This law will be apparent from an examination of the figures given. (See Plate XVIII.)

Colour. — The colour of fat is subject to considerable variations, but it usually exhibits a tinge, more or less deep, of yellow. The fat of young animals is usually of a lighter colour than that of the full-grown and aged; this may be seen by a comparison of the fat of an infant with that of an adult, or of the fat of the calf with that of the ox; in the former it is almost white, while in the latter it frequently exhibits a deep and golden hue. The differences of colour referred to doubtless denote differences in the relative proportion of the different constituents of fat.

In some animals, also, fat of various bright colours is encountered, especially in Birds, beneath the skin of the beak and of the feet; in the Crustaceæ and in some of the Reptilia. In the Triton the fat is of a deep orange colour, approaching to red. The coloration of the iris of birds depends, according to Wagner, upon a fat which is accumulated in drops, and perhaps also in cells.

Consistence. — The consistence of fat is different in different animals, and also varies in accordance with the temperature; thus the fat of the pig is softer than that of the ox or sheep; that of the human subject is intermediate between both in its consistence, and all kinds of fat are harder in cold than in warm weather. The variation in the solidity of fats depends upon the amount of stearine and elaine which they contain; the hard fats containing a greater quantity of stearine than the soft fats, in which the elaine is greatest.

Structure. — Most observers agree in assigning to each fat vesicle a distinct investing membrane, notwithstanding which fact the proofs adduced by them of the existence of such a structure are by no means so decisive as to render such a conclusion anything more than doubtful: thus micrographers, hitherto have been unable to demonstrate the presence around normal fat vesicles of an enveloping tunic, but have been contented to rest their opinion upon the indirect and uncertain evidence to be derived from a knowledge of the action of re-agents; upon testimony, in fact, analogous to that upon which Henle and Mandl decided in favour of the existence of a membrane surrounding the milk globule.

Schwann, indeed, states that he found the membrane of the fat cell to be almost as thick as the blood globule of man in an infant affected with *mollities ossium.*[*]

Henle also has observed around the obscure periphery of a fat cell a strait and clear band, but could not assure himself that this was not the result of an optical illusion.[†]

The above are the only trustworthy observations of a direct character recorded in proof of the existence of a distinct tunic to the fat vesicle, and they are evidently not of a satisfactory or decisive nature.

The indirect testimony procured from a knowledge of the action of re-agents is as follows: — Ether is stated to render the contents of the fat vesicle fluid and transparent, without, at the same time, diminishing its size, as is proved by the fact that on the re-solidification of its contents, the vesicle presents the same form and dimensions as at first.

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[*] Mikroskopische Untersuchungen, p. 140.

[†] Anat. Gen. p. 422.

Again, acetic acid, according to Henle, acts upon the fat vesicle as upon the milk globule, destroying the membrane in different places: it permits the escape of a number of globules of oil or grease, which, like pearl-drops, remain attached to the larger vesicle.

Ether, however, produces other effects than those usually described, and which are mentioned above; thus, when applied to the fat vesicles of the pig, many of them will be seen to burst, and to collapse frequently to less than the fourth of their original size, losing, at the same time, all definite form, and, in proportion as the vesicle collapses, one large circular drop, or two or three smaller ones, will be seen gradually to form around and envelope the shrunken vesicle, which is, however, never entirely dissolved.

There are other observers again, as Schwann and Henle, who consider that fat vesicles are not merely provided with an envelope, but that they are true cells possessing both cell wall and nucleus.

Thus Schwann noticed in the wall of the fat vesicles of the child already referred to a nucleus of round or oval form, sometimes flattened, and sometimes not so.

Furthermore Henle writes, "very frequently the wall presents a salient point on some part of its extent, and in that position exists a nucleus, or a trace of a nucleus. Sometimes there are two nuclei, and in very many cases they cannot be observed at all."*

Again, Mandl has made the observation in examining the fat tissue of young rabbits, and especially in taking the little masses of fat which lie along the vertebral column in the interior of the pectoral cavity, that the vesicles appear but half filled, and that they consist of two parts, an inner one conveying the aspect of a drop of oil, and an outer membranous portion.†

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* Anat. Gen. p. 422.

† Anatomie Microscopique, p. 141.

Such are the facts hitherto recorded in favour of the presence of a nucleus in the fat vesicle: it will be seen that although they are more definite and satisfactory than those adduced in proof of the existence of an investing membrane, yet that they are scarcely in themselves sufficient to set at rest the question of its cellular nature.

The observations then cited above, while they fail to demonstrate sufficiently the true organisation of the fat vesicle, yet render it extremely probable that it is really cellular. In favour of this view, a few additional observations have occurred to myself, which are conclusive on one of the two debated points of the organisation of the fat vesicle. The first have reference to the outer membrane. If a thin slice of any of the softer fats placed between two plates of glass be pressed firmly, though not with too great violence, and subsequently be examined with the microscope, it will be seen that the vesicles have not run into each other, but still preserve their individuality.

Again, ether applied to the fat vesicle does not entirely dissolve it; even when it causes it to burst and collapse, a residue always remains, and this probably is membranous.

Furthermore, if a thin slice of fat be placed between two plates of glass, and having been forcibly compressed, be examined with the microscope, it will be seen that some of the vesicles have burst, discharging a portion of their contents, the membrane of the fat vesicle then becoming visible, and declaring its existence by certain folds and markings, into which it falls on the escape of its contents, and by the jagged outline of the rent through which those contents passed. (See Plate XIX. *fig.* 2.)

Finally, decomposition produces an effect somewhat analogous to that occasioned by pressure; the fat vesicles burst, and their fluid contents escape, leaving the membrane in most cases entirely empty, and which, as well as the aperture in its parietes, may be easily detected with the microscope; the soft contents of the vesicles break up and resolve themselves into globules of an oil-like appearance. (See Plate XIX. *fig.* 4.)

The second set of observations relate to the nucleus.

If a thin slice of the fat of the pig be pressed as before between two slips of glass with a moderate degree of pressure, and then be submitted to the microscope, in very many of the cells will be seen a dark nucleus-like body. This experiment will not, however, always succeed. (See Plate XIX. *fig.* 1.)

A body of a similar description, but of a more defined form, is very frequently encountered in the decomposing cells of marrow fat; this nucleated condition of the cells preceding their rupture. (See Plate XIX. *fig.* 3.)

Again, in some fat cells contained in a small encysted tumour removed from over the nasal bones, and kindly sent to me for examination by W. H. Ransom, Esq., of University College Hospital, (to whose zeal and intelligence I am indebted for many interesting specimens of morbid structure,) nucleoid bodies were distinctly visible even without pressure, although they became more apparent after a gentle degree of compression had been applied. (See Plate XIX. *fig.* 6.) The apparent nuclei in the cases related differed from each other somewhat, being more defined and darker in the two latter than in the former; the cells themselves too were not identical in appearance; thus the margins of those of the pig and of the human marrow fat were smooth and distinctly defined, while those from the tumour were less regular and distinct. (See Plate XIX. *figs.* 1. 3. 6.)

Now these nucleus-like bodies in the several cases mentioned, although occupying the position of nuclei and presenting the appearance of such, it is very possible were not in reality true nuclei; it seems to me that their formation might be accounted for without any reference to a nucleus. Thus with respect to the nucleoid bodies in the cells of the pig produced by pressure, their formation might be explained as follows: the mutual compression of the fat vesicles upon each other would tend to occasion a condensation of the semi-fluid contents in the centre of each, and in this way the appearance of nuclei would be produced.

Again, the semblance of a nucleus in the decomposing cells might be supposed to depend upon the partial escape by endosmosis of the contents of those cells, the portion remaining in them representing a nucleus merely from the position occupied by it in the centre of the cells.

The formation of the nucleated bodies in the third case would seem to point to and to require a different explanation. Decomposing fat frequently exhibits a crystalline arrangement: now it is conceived that the outer part of each vesicle had become softened and broken down in consequence of commencing decomposition or of disease preparatory to its assuming the crystalline form, the central part at the same time remaining unaffected.

It will be seen that the preceding observations, in relation to the presence of a nucleus in fat vesicles, are not decisive, although they add weight to those of anterior observers, and render it still more probable that they are really nucleated cells.

The facts adduced, however, in reference to the existence of an investing membrane are quite conclusive.

On the vesicles of decomposing human fat, it is a common occurrence to meet with stelliform figures, each being composed of a number of delicate striæ radiating from a central point. On the smaller vesicles but a single figure of this description will usually be met with, but on the larger there may be three or four. When but one is present, it usually covers about a third of the surface of each vesicle. (See Plate XIX. *fig.* 5.)

Henle * observes of these that they might be metamorphoses of the nuclei of the cells; "nevertheless," he says, "they have more analogy with crystalline deposits."

The occurrence of two, three, or four of these on the same cell is opposed to the idea of their connexion with the nuclei; and the observation of Mandl, who noticed their formation on butter, is conclusive on this point. †

Vogel ‡, as also Gerber §, regard the figures in question as groups of crystals of margaric acid.

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* Loc. cit. p. 423.

† Anat. Mic. f. 143.

‡ Anleitung zum Gebrauche des Mickroskops, p. 289. tab. 111. fig. 2.

§ Gerber's General Anatomy, translated by Gulliver.

Distribution. — The fat vesicles are distributed in groups, which lie near to and follow the course of the blood-vessels. (See Plate XVIII. *fig.* 1.) This arrangement is particularly evident in the mesentery and omentum, and may be compared to that of a bunch of grapes, the fat vesicles representing the grapes, and the vessels the stalks of the bunch: in one particular only does the comparison fail; thus each grape of the bunch receives and is attached to a separate pedicle, which is not the case with the fat vesicles, although one observer has asserted that a separate vessel is distributed to each vesicle. The groups of fat vesicles occurring in young animals, in which each globule is circular, may be compared to heaps of shot piled up upon each other.

In those situations in which the fat occurs in thick and dense masses, the arrangement referred to is somewhat different. The fat vesicles are still parcelled out into groups by means of intersecting cellular bands; but the several groups lie in close contiguity, instead of being, as in the former case, separated from each other by distinct intervals. Throughout these masses, too, but few blood-vessels are distributed.

The intimate arrangement of the fat vesicles having been thus briefly sketched, it remains to describe the general distribution of fat throughout the body.

In man, fat is developed principally in the loose cellular tissue; it is encountered forming a layer of variable thickness in that which is situated immediately beneath the skin; in the serous membranes, as in the omenta, the mesenteries, and the epiploa; on the surface of the heart, and around the kidney.

In certain situations the subcutaneous fatty layer experiences an increased development designed to fulfil certain peculiar intentions; thus, in the soles of the feet, the palms of the hands, in the female breast, in the region of the pubis, and over the glutei muscles, especially over those of the Hottentot women, fat is developed usually in considerable quantities.

This superficial layer of fat is also generally thicker in children and in women than in men.

Again, there are other peculiar situations in which fat is almost invariably encountered, as in the orbit, in the articulations, where it constitutes the glands of Havers, in the shafts of the long bones forming the marrow, in the vertebral canal, and in many other localities where vacancies occur which require to be filled up. The marrow differs only from ordinary fat in that the cells composing it are more circular, with but little admixture of cellular tissue.

On the other hand, there are situations in which, under no circumstances, is fat developed, as in the eyelids, in the axillæ, between overlapping muscles, and in the genital organs.

Quantity. —The amount of fat varies greatly in different species of mammalia, in different individuals of the same species, and in the same animal at different times.

Thus certain animals seem to have a peculiar aptitude for the formation of fat, as the pig.

Again, the various members of one family are sometimes observed to be remarkable for the constitutional predisposition exhibited to the formation of fat. Again, other families are met with equally remarkable for their indisposition to fatten.

Lastly, in some animals the fat accumulates at particular periods in greatly increased quantities, as in the hibernating mammalia, and in the larvæ of insects. In man the fat usually undergoes an augmentation after the meridian of life has been passed.

Castration peculiarly predisposes the system to the formation of fat.

Occasionally, also, fat is secreted in vast and abnormal quantities: where this augmentation is general it constitutes the diseased condition of obesity; and where it is only partial it gives rise to tumours, often of great magnitude.

In general, a certain degree of fatness argues a healthy and vigorous condition of the system, while its excess or inordinate accumulation denotes either a degree of weakness of constitution or a peculiar and unexplained state of the system.

Disappearance. — Of all the solids in the body, fat is developed and destroyed with the greatest rapidity: in illness, it disappears with surprising quickness, and is formed again, under the influence of recovery with almost equal celerity.

The exact changes which occur during the disappearance of fat are unknown; whatever they may be, they doubtless affect each individual fat vesicle throughout the body, and their nature being ascertained in a single cell would serve to explain the disappearance of fat over the entire body. It is uncertain whether the contents of the vesicle disappear, the membrane remaining, or whether both are effaced together. Béclard says that the fat vesicles themselves disappear.* Hunter, on the contrary, assures us that they may be distinguished even when they are empty.† Gurlt states that they contain serosity in place of grease in lean animals.‡

The immediate cause of the disappearance of fat most probably depends upon interrupted nutrition; the contents of the cells escaping through their walls become absorbed by the lymphatics, and thus removed into the circulation. This view is supported by the observation of Henle, who states that, after repeated losses of blood, the quantity of grease in the blood augments considerably, on the surface of which it is often seen swimming as a cream or pellicle.

Uses. — The uses of fat are manifold and important.

1st. It serves to impart softness to the texture of the skin.

2nd. It adds grace and symmetry to the outlines of the body.

3rd. In certain situations, as in the soles of the feet, in the palms of the hands, and over the glutei muscles, it serves as a protection against the effects of pressure.

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* Anatomie Générale, p. 163.

† Remarks on the Cellular Membrane in Med. Obs. and Inq., vol. ii., London, 1757.

‡ Physiologie, p. 20.

4th. Being a bad conductor of caloric, it prevents the too rapid dissipation of the heat generated in the system.

5th. It is to be regarded as a reserve store of nourishment set apart by the system during the period of its health and strength, and designed to meet certain exigencies, when the inherent powers of the constitution are called into requisition, as in times of hunger and sickness.

Distinctive Characters of Oil Globules. — The contents of fat vesicles are, as already stated, of an oleaginous nature, which when they escape from the vesicles assume the form of oil drops; these are often met with in the various fluids and solids of the system apart from the fat vesicles, from which it is necessary that they should be discriminated. There are several characters by which oil globules may be distinguished from true fat vesicles; thus they are of a fluid nature, are usually perfectly spherical, and on account of their fluidity, in place of being globular are generally flat; they are seen sometimes to alter their shape, as when they roll over on the surface of the object-glass or come in contact with obstacles; they reflect the light less powerfully, and lastly, the slightest degree of pressure causes them to coalesce.

There is but little probability of confounding oil globules with air bubbles; these have a different colour, reflect the light differently, and are perfectly globular.

Art. IX. EPITHELIUM.

As the external surface of the body is invested with a cuticle which has received the name of Epidermis, so are its internal free surfaces in like manner clothed with a delicate pellicle which has been denominated Epithelium.

Both the epidermis and epithelium are constituted of cells: there is this difference, however, between them, that while the former, by the intimate union and superimposition of its cells, exists as a distinct and continuous membrane, the latter, owing to the feeble cohesion of its constituent cells, can scarcely, except in certain situations, be shown to exist as a united and extended structure.*

The epidermis and epithelium are therefore hardly to be regarded as distinct structures, but rather as the same, the differences observed between them being merely modifications, the result of the different circumstances to which they are each subject.

The essential identity of the two may be shown by an examination of the epidermis at the outlets and inlets of the body, where, by gradual transition, it may be traced inwards into the condition of epithelium; and this also, traced from within outwards, will be observed gradually to acquire the characters of epidermis; so that, within a certain distance of the termination of the cavities of the body, which open externally, the epithelium may also be demonstrated as a distinct membrane; this membrane may be followed in man from the lips as far backwards as the posterior part of the mouth, also passing over the tongue; and in the horse and in birds it may be shown to exist in the stomach and gizzard.

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* Leeuwenhoek first discovered in the mucus of the vagina little scales, which he presumed formed the internal membrane of that canal, and from which he conceived they become detached by coitus. (Opera, t. i. p. 153. 155.) He likewise noticed that the mucus of the mouth contained scales, (Ibid. t. iii. p. 51.), and he saw also the cylindrical epithelial cells of the intestinal cavity. (Ibid. p. 54. 61.)

The epithelium will be first described, inasmuch as its organization would appear to be more simple than that of the epidermis, which, by modifications of its cells, is converted into so many apparently distinct structures.

It has been remarked that the internal free surfaces of the body are covered by epithelium: these surfaces comprise those of both the open and the closed cavities, the former of which include the alimentary canal from mouth to anus, the genito-urinary organs and passages of both the male and female, and the respiratory track, consisting of the trachea, bronchi, cells of the lungs and nares; the latter consist of the great serous sacs of the head, chest, and abdomen, and the lesser ones of the pericardium, tunica vaginalis, the cavities of the joints, and of the lymphatic and blood vessels, including the heart.

The bursæ are said by Henle* not to be furnished with an investing epithelium, — a statement to be received with some degree of hesitation.

It would appear, therefore, that, with the single doubtful exception alluded to, every free surface of the body is invested with its own appropriate epithelium, the ventricles of the brain even being lined with an epithelium proper to them, and the surface of the cornea being covered with one also. The existence of an epithelium in this latter situation may be directly proved by means of the microscope; and it may be inferred from the observation of the fact, that in the general casting of the epiderm of snakes and other reptiles, a delicate film is likewise thrown off from the surface of the cornea.

The epithelium has not the same character in the different situations in which it is encountered, but the cells of which it is composed differ in form and size, according to age and the locality occupied by it.

The several varieties of epithelium may be reduced into two principal types, in the first of which the cells are more or less circular or polygonal, and in the second are elongated and conoid. These two forms may be distinguished by the appellations of *Tesselated* or *Pavement Epithelium*, and *Cylindrical* or *Conoidal Epithelium*. (See Plate XX. *fig*. 1. and 2.)

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* Anat. Gén. vol. vi. p. 225.

The Conoidal Epithelium admits of subdivision into *Naked Conoidal Epithelium* and *Ciliated Conoidal Epithelium*.

TESSELATED EPITHELIUM.

Form.—The cells of this description of epithelium form many layers, are flattened, and either circular, polygonal, or irregular in outline: the younger cells are mostly of the first shape, and are thicker than the older ones, which are irregular in form, thin and membranaceous, while the polygonal cells are encountered more particularly in certain situations, as on the choroid plexus, pericardium, and serous membranes in general. The polygonal shape is produced by the mutual compression exerted by the cells upon each other, and consequent adaptation.

Size. — The size of the cells of pavement epithelium varies both according to age and locality; the younger and deeper seated cells are of course smaller than the older and more superficial ones; the larger cells are met with in those situations where the epithelium is continuous with the epidermis, as in the mouth and œsophagus, the vagina, urethra, and bladder, the commencement of the rectum, the inferior division of the nares, lining the eyelids, and covering the cornea. (See Plate XX. *fig*. 1.) On the contrary, the epithelium of the pericardium, ventricles, aorta, and of most of the closed cavities is composed of cells which are very much smaller in size than those of the localities previously enumerated. (See Plate XXII.)

Structure. — Epithelial cells illustrate faithfully the doctrine of cell development, each consisting of a nucleus, cell wall, and intervening space enclosing fluid, both the nucleus and the cell wall exhibiting a granular composition.

It has been observed, that the younger cells are thicker than the older and fully developed ones, which become reduced to mere membranous expansions, from which it follows that the space intervening between the nucleus and cell wall is greatest in the younger cells, while it is almost obliterated in the older. The smaller cells are also more granular than the larger: now these two facts stand in close relationship with the function discharged by these cells, and which is so much the more active as the cavity is large and the granules numerous.

The nucleus is likewise best seen in the younger cells: in the older ones it becomes either entirely obliterated, or it escapes from the cavity of the cell, the position which it previously occupied in it being indicated by a depression; it is for the most part circular; but occasionally, and particularly in certain localities, it is found to be oval, as in the epithelium of the lower two-thirds of the uterus, in that of the pericardium, and also in that of the blood vessels, the aorta excepted: it sometimes occupies a central position in each cell; at others it is excentric.

The properties of pavement epithelial cells, as well as their form, size and granular texture, alter also with age: thus the younger cells are dissolved, with the exception of the nucleus, by acetic acid, whilst the same re-agent applied to the older ones produces scarcely any appreciable effect.

Epithelial cells, on the addition of water, or after death, become white and opaque — a common effect of water on all animal structures. The change in the case of the epithelial cells probably depends upon the coagulation of their fluid contents; and to it the characteristic dulness of the eye after death is due.

Distribution. — This form of epithelium is more extensively distributed than the conoidal variety: it is encountered on the free and serous surfaces of all the closed cavities, as of the cranium, thorax and pericardium, abdomen and tunica vaginalis, lining the lymphatic and blood vessels, even the ventricles of the brain itself, in which it rests immediately upon the cerebral substance are not free from it: it is met with likewise near the terminations of those cavities which open externally, as in the mouth, where it extends as far backwards as the cardiac extremity of the stomach, in the lower portions of the nares, whence it passes into the frontal sinuses; in the vagina and uterus, the lower two-thirds of which it lines, as also the urethra. In the male subject it passes over the glans penis, and then enters the urethra.

The epithelium of the urinary apparatus should perhaps be referred to the pavement epithelium: its cells however vary very considerably in form: thus many of them decidedly resemble the variety of epithelium under discussion; others, however, are clavate, the narrow or fixed extremity being often produced into a long thread or filament; and again, others imperfectly represent the conoidal variety of epithelium: these last, as well as the clavate cells, are met with in the greatest quantity in the upper part of the bladder, and in the ureters.

CONOIDAL EPITHELIUM.

Form and Size. — The cells of this form of epithelium are much more regular in size and shape than those of the tesselated or pavement kind: the term cylindrical usually applied to them is, however, far from accurate, since they do not possess, even in a slight degree, the outward form of a cylinder: the word conoidal, here used, serves to express much more closely the real form of the cells of this variety of epithelium, although it fails to give an exact idea of their shape: thus the cells in question are not merely conical with flat summits, but each cone is flattened at the sides, so that when the bases of the cones are seen directly, they exhibit the appearances of ordinary polygonal tesselated epithelium; the side view of the cells will at once make manifest their distinctness. (See Plate XX. *fig.* 2.)

Conoidal epithelial cells are usually disposed more or less vertically to the surface upon which they rest, their narrow extremities being turned downwards, and attached to that surface, and the broader and free ends being directed upwards.

Structure. — The cells of conoidal epithelium have precisely the same structure as those of the previously described kind; that is, they consist of nucleus, cell wall, granules, and fluid contents: the chief difference is one of form and not of structure.

The nucleus is almost invariably oval, the long axis corresponding with that of the cell itself: it is often so large as to occasion the cell to assume a ventricose form, it being contracted immediately above and below the part in which the nucleus is situated. Some observers speak of two nuclei in a single cell: this, however, must be an exceedingly rare occurrence, as I have never yet met with a single example of the kind.

The conoidal epithelium is, as already remarked, divisible into two kinds.

Naked Conoidal Epithelium.

Distribution. — This subdivision of epithelium, to which the description just given more immediately applies, is met with investing the mucous membrane of the alimentary canal, extending from the cardiac extremity of the stomach to within two or three inches of the rectum; it is encountered likewise lining the several ducts and prolongations which communicate with this: thus this form of epithelium exists in the gall-bladder, where it is of a deep yellow colour, in the ductus communis choledocus, in the pancreatic duct, and in the mucous crypts or follicles imbedded in the mucous membrane. It is found also in the upper portion of the nares, in the salivary ducts, in the appendix vermiformis, and in a modified form in the vas deferens.

In the stomach, the naked conoidal epithelium does not exist in an unmixed form; it occurs intermixed with pavement epithelial cells, probably derived from the œsophagus, and carried down during deglutition.

It is in the gall-bladder, the small intestines and the appendix vermiformis, that the naked conoidal epithelium exists in the greatest perfection.

Ciliated Conoidal Epithelium.

The cells of this variety of conoidal epithelium agree precisely in form, size, and arrangement with those of the first described subdivision, the only difference being, that they are possessed of the singular addition of vibratile ciliæ.* (See Plate XXI. *fig.* 3.)

The ciliæ taper from base to apex, are attached to the thickened margins of the summits of the cells, ten or twelve of them belonging to each. In the frog they would appear to be not merely attached to a circular line, but also to the segment of the cell described within this. (See Plate XXI. *fig.* 1.)

During life the ciliæ are in a constant state of activity: the power by which their motions are effected is, however, involved in the greatest obscurity: it can scarcely be the result of muscular structure, as some have supposed, since the entire cilia is many times smaller than the smallest muscular fibre. The idea has been put forth that the ciliæ are hollow; that they communicate with a vessel which runs along their bases, containing fluid; and that they are moved by the successive injection and expulsion of this fluid.

One fact has been observed, which affords countenance to the above explanation of the motion of the ciliæ, viz., that this takes place in a determined direction: commencing in the ciliæ on one side, it runs along them to the opposite, the several ciliæ being thus successively called into action. It is this peculiar character of the motion of the ciliæ which has led to its comparison with the waving of a corn-field over which the wind passes in successive gusts. The motion, in whatever way effected, is singularly beautiful, and, strange to say, exhibits many of the characters of volition: thus it will sometimes cease altogether for a time, and then suddenly commence again. It is also sufficiently powerful to effect the entire displacement of the cell or corpuscle to which the ciliæ are attached, and many of which may frequently be seen moving freely and quickly about, usually in circles, in the field of the microscope. This curious spectacle is most readily witnessed in the ciliary cells of the trachea of the frog, which are of a different form from those of the mammalia, being rounded in place of elongated and conoidal. (See Plate XXI. *fig.* 1.)

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* To Purkinje and Valentin especially belong the honour of making known in all its extent the phenomenon of ciliary motion, and which before that time had been observed only in some few of the lower animals, and concerning the nature of which many errors prevailed. They discovered it in the respiratory and female genital organs in 1834. (Muller, Archiv. 1834, p. 391.)

The combined motion of the ciliæ is also capable of putting in movement either fluids or solid particles which may come into contact with them. This fact those who are given to microscopic investigation will have had many opportunities of verifying, and one may easily at any time acquire the proof of it by mixing with the fluid in which the ciliæ are acting some fine powder, as, for example, of carbon.

The motion of the ciliæ, when acting in combination, is stated to take place always in a determined direction from within outwards. It would appear, however, from the observations of Purkinje and Valentin * that the direction is capable of reversion: thus, these observers saw the accessory branchiæ of the anodon vibrate during from six to seven minutes in one direction, and afterwards, during the same lapse of time, in an opposite.

The influence of physical and chemical reagents upon the vibratile movement has been carefully examined. Thus, if a portion of vibratile epithelium be touched or scraped, the motions of the ciliæ will become more active, and sometimes commence again even after they had become extinct. They cease at a temperature below the freezing point, and at a degree of heat sufficient to occasion the coagulation of the animal fluids. Galvanism destroys their action, but in a local manner, — a fact which a reference to the constitution of epithelium by the union of separate cells may serve to explain. Amongst chemical reagents, narcotics are without influence; acetic and the mineral acids destroy the motion, as also caustic ammonia, nitrates of potash and of silver. The serum of the blood prolongs its duration. Urine and white of egg are without effect upon it. Bile instantly destroys the activity of the ciliæ.

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* Motus Vibrat, p, 67.

The ciliary motion soon ceases after death in the mammalia, but continues in many of the invertebrata, and especially in several of the mollusca, as for example, in the river muscle and the oyster, for days after the death of the animal.

It would appear, therefore, that each ciliated corpuscle bears the closest possible resemblance to many of the infusory animalcules, and it is questionable whether its claim to be regarded as a distinct entity be not equally strong.

Distribution. — Ciliated epithelium has not been as yet discovered amongst the mammalia in any closed cavity, but always in situations which communicate with the air; thus it is met with, as is generally known, lining the trachea and bronchi, extending even to their minutest ramifications; again, it is encountered in the fallopian tubes, and lining the upper third of the cavity of the uterus of adult animals, but not that of young mammalia. There is yet another locality in which I believe it also to exist, viz. in the convolutions of the tubuli seminiferi of the epididymis.

On the other hand, there are many situations in which it has been repeatedly asserted to exist, but in which patient and repeated investigation has failed to reveal its presence, as for example, in the ventricles of the brain *, covering the pia mater, and lining the eyelids and frontal sinuses.†

The epithelium of these several parts, on the contrary, is pavement and not ciliated epithelium. (See Plate XXIV.)

Purkinje ‡, in describing the epithelium of the ventricles, does so most circumstantially, and states that he followed the vibratile movement in the sheep from the lateral ventricles through the third ventricle, and by the aqueduct of Sylvius into the fourth.

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* Purkinje in Muller, Archiv. 1836, p. 289.

† Henle, Anat. Gén. t. vi. p. 252.

‡ Muller, Archiv. 1836.

Valentin * confirms the accuracy of this description as regards man.

We find Henle † describing the epithelium of the ventricles as a cuneiform ciliated epithelium; and in Gerber's General Anatomy, we remark that it is stated to be a tesselated ciliated epithelium. It is singular how so great an error could have originated, and still more so how it could have been so long perpetuated.

DEVELOPMENT AND MULTIPLICATION OF EPITHELIUM.

Each epithelial cell is first detected as a nucleus without any appearance of cell wall around it: this however may exist closely embracing the nucleus, even from the earliest period at which this can be observed. After a time, however, a transparent border becomes visible, surrounding the nucleus: the width of this goes on gradually increasing until at length the full dimensions of the cell have been attained: now the outer limit of this border doubtless indicates the cell wall, the clear space between it and the nucleus being in the younger epithelial cells filled with fluid. In the conical epithelium the cell wall is not developed equally around the nucleus as in the pavement epithelium, but chiefly in two opposite directions.

It has been observed, that young epithelial cells are thicker and rounder than the older ones; it has also been remarked, that they are more granular; facts which stand in close relation with their functional activity.

It has been noticed likewise, that the nucleus in the progress of development becomes either obliterated, or that it escapes from the cell. Now it has struck me that this disappearance of the granular nucleus and granules of the cell wall might possibly be connected with the reproduction or multiplication of epithelial cells, as well as of cells occurring elsewhere than in the epithelium, and that each granule might in reality be an epithelial cell in embryo. This is

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* Repertorium, 1831, p. 158. 278.

† Anat. Gén. t. vi. p. 253.

of course but a conjecture: it is one, however, which would appear not to be contradicted by any other known fact, and to have analogy in its favour; the mode of reproduction amongst the lower algæ being precisely similar.

The occurrence of two nuclei in the same cell has been recorded by some observers, and who have from this fact drawn the inference, that epithelial cells are multiplied by division. This method of increase cannot, however, be presumed to prevail to any extent, since it is a circumstance of extreme rarity to meet with two nuclei in the same cell.

NUTRITION OF EPITHELIUM.

The epithelium has no immediate or structural connexion with the parts which lie immediately beneath it, neither does it receive blood-vessels and nerves from those parts; it is simply dependant upon them for the supply of nourishment, of which it is the recipient, and which is derived from the blood-vessels distributed throughout the tissue of the true skin lying beneath it, and from which vessels the plasma is continually escaping by transudation or exosmosis.

DESTRUCTION AND RENEWAL OF EPITHELIUM.

The epithelium in every part of the body is continually undergoing a process of destruction, and consequent renewal.

It is less easy to establish the fact of the destruction of the epithelium in the closed cavities than in the open; nevertheless, that it really does take place even in these, may be inferred from the observation of the fact that the cells of epithelium encountered in such localities represent every degree of development, many of the older ones also being destitute of nuclei, and more or less broken into fragments. It is probable, however, that the process of destruction is slower in the closed than in the open cavities.

In the open cavities, the destruction of epithelium is doubtless more considerable and more rapid; it is also more easy to determine in these: thus during mastication, deglutition, and digestion, a considerable amount of epithelium becomes disturbed, removed from the surface to which it was attached, and mixed up with the saliva, mucus, gastric fluid, food, &c., and finally is discharged from the system with the fœces, in which by microscopic examination it may readily be detected.

The fact of the gradual and continual destruction of epithelium may likewise be ascertained by an examination of the several fluids discharged from the system, as the saliva, the mucus, from either mouth, nose, lungs, urine, seminal or menstrual fluids, in all of which the microscope will reveal an abundance of epithelial cells.

The same fact may also be determined by a microscopic examination of the scum which collects during the night on the lips and around the base of the teeth of many persons.

In certain situations the epithelium undergoes not merely a gradual, but also a periodical destruction, as in the uterus at the monthly periods and after parturition.

The continual destruction of epithelium having been thus rendered manifest, its renewal follows as a matter of necessity.

In irritation of the mucous membrane of the bronchi, nose, and alimentary canal, it is possible that the epithelium, during the period of the continuance of the irritation, is entirely destroyed.

USES OF EPITHELIUM.

The first use of the epithelium is a passive one, it serving like the epidermis as a protection to the more delicate parts which lie immediately beneath it.

The second use is active, the epithelium doubtless being an important agent in secretion.

Each epithelial cell may be regarded as a gland reduced to its most simple type or condition, it embodying all that is essential in the largest and most complex secreting organ, viz. the true secreting structure.

The nature of the fluid secreted by epithelial cells is not everywhere identical, but varies according to their exact structure and the locality in which they are found: thus in some situations they secrete serum, as in the serous sacs; in others mucus, as in the mouth, nose, alimentary canal, &c.; in others synovia, as in the joints; in the stomach and in the duodenum, they assist in the elaboration of the fluids which are there found.

That the epithelial cells are the real agents engaged in the production of the several fluids named, is rendered certain by the facts that they correspond precisely with the undoubted secreting structure of true glands; and further, that in the situations where they are found, no other organisation exists to which the function of secretion could with any degree of probability be assigned.

The importance of the office discharged by the epithelium explains, then, the universality of its distribution.

The diffusion of epithelial or secreting cells over the surface of membranes which require to be kept continually moistened by a suitable fluid, affords a beautiful example of the wise adaptation of means to an end: by no other means than that employed could the end in view be so surely accomplished or with so great an economy of space.

The above described uses of epithelium are common to it wherever encountered: the third use is mechanical, and accomplished only by the ciliated form of epithelium.

It has already been observed that the force of the combined action of the ciliæ is so great as to enable them to carry along with or drive before them fluids, and even solid particles which may happen to come in contact with them: it has likewise been remarked that the direction of their united action is invariably from within, outwards or towards the outlets of the body; at least it is so amongst the mammalia. From a knowledge of these facts it is not difficult to suggest the probable use of vibratile epithelium in the localities in which it has hitherto been discovered in man and the mammalia.

Thus in the bronchi and trachea, it may be presumed to be designed to facilitate the escape from those passages of any foreign particles which may have found entrance to them.

Again, in the fallopian tubes and upper portion of the uterus, it can scarcely be questioned, but that its use is to hasten the progress of the ovum from the ovary to the uterus; and, presuming that the direction of the action of the cilia may be, and is sometimes reversed, the vibratile epithelium of these parts may be further intended to insure the more speedy transmission of the seminal fluid along the fallopian tubes to the ovary, upon which it has been detected by more than one observer.

Art. X. EPIDERMIS.

The entire of the external surface of the body is invested with a membrane which has been denominated epidermis, formed of superimposed layers of nucleated cells (see Plate XXIV. *fig.* 3.), and the number of which layers is greatest in those situations in which the membrane is subject to the most pressure, as in the palms of the hands and soles of the feet, in which the epidermis sometimes attains the thickness of the $\frac{1}{16}$ or even the $\frac{1}{8}$ of an inch.*

The form, structure, and development of the cells composing the epidermis are in every respect identical with those of the tesselated variety of epithelium already described; thus, first, the younger and deeper-seated cells are spherical in outline, and almost globular, while the older and more superficial cells become irregular in form, expanded, thin, and membranaceous; secondly, like those of the tesselated epithelium, the cells consist of a nucleus, cell wall, cavity, and granules; it is, however, worthy of remark, that the nucleus, as well as the majority of the granules contained in the epidermic cells, disappear at an earlier period of development than do those of the epithelium, facts which will be explained when the uses of the epidermis come to be treated of; thirdly, the plan of development is the same in the two cases, the cell wall being developed around the nucleus, which is the part first formed.

Thus far then there is a close correspondence between the epidermis and epithelium, so close indeed as to make it apparent that the two are but modifications of one and the same structure. The chief respects in which it differs from the epithelium are in the compact and firm union of the cells with each other, whereby it forms a distinct and continuous membrane, and in the paucity of granules dispersed throughout the cells.

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* Leeuwenhoek first observed that the epidermis was composed of scales placed one against the other, and also that, after a certain lapse of time, they were cast off and their place supplied by others.

The epidermis also stands in precisely the same relation with the parts beneath it as the epithelium; thus, it has no structural connection with those parts, and receives neither blood-vessels nor nerves from them, but is simply dependent upon them for the plasma which is continually escaping from the blood-vessels of the true skin. This want of structural connection is shown by the fact that a portion of the cuticle may be detached without its removal occasioning either pain or hæmorrhage.

This separation of the epidermis from the dermis frequently takes place during life, as from a burn, scald, or blister, or from the effusion of serum, the result, not of injury, but of disease. After death and on the commencement of decomposition, the epidermis may be detached in large masses, the prolongations sent down to the sebaceous and sudoriferous glands also coming away with it.

The epidermis does not merely cover the whole external surface of the body, but sends processes into its various outlets, as the mouth, nose, rectum, vagina, and male urethra; these prolongations soon lose, however, the characters of epidermis, and acquire those of epithelium.

The epidermis likewise sends down processes into the sebaceous and sweat glands, and which, forming a perfect tube, serve to convey the secretions of those glands to the surface, on which they open as raised and rounded papillæ, with central depressions and apertures. (See Plate XXIII. *figs.* 1 and 2.)

A sheath of epidermis likewise encircles the base of each hair.

The number of these infundibuliform processes and salient papillæ which open on the surface is immense, and may be stated at about 3000 to the square inch, which, computing the number of square inches of surface in a man of average size at 2500, would give 7,500,000 for the entire surface of the body.

In addition to the papillæ, we observe on the surface of the epidermis a great number of lines or furrows which map it out into a network of small polygonal and lozenge-shaped spaces; these are of two kinds, the one large and coarse and corresponding with the flexures of the joints; the others smaller, occupying the interspaces between the larger, and also being generally distributed over the surface of the epidermis, where the articular furrows have no existence. The plan of arrangement of the smaller lines is as follows: — a number of straight lines, usually from six to ten, radiate, like the rays of a wheel from its centre, from each hair-pore; these usually come in contact with the lines proceeding from other hairs. These radiating lines thus mark out the surface into triangular spaces, between which are usually situated two or three other pores, those of the sebaceous and sweat glands; from each of these also similar radiating lines proceed; these unite with the coarser lines given off from the hair follicle, and occasion a still further subdivision of the surface of the epidermis into triangular spaces. The result of this minute subdivision is to occasion the whole surface of the epidermis to assume a minutely and beautifully reticular appearance. The coarser lines are best seen in the palms of the hands and soles of the feet, while the smaller and finer lines may be readily traced, following the disposition just described on the back of the hand.

The effect of water in rendering the cells of tesselated epithelium white and opaque has been referred to: its long-continued application to even the living epidermis produces a similar result, which most persons must have observed, although some would be at a loss to account for it; thus, the skin of the fingers of those who have been engaged in washing for some hours becomes of a pearly whiteness.

It sometimes happens that epidermic cells are developed in increased and abnormal quantities, giving rise to tumours, and which are by no means of uncommon occurrence.

EPIDERMIS OF THE WHITE AND COLOURED RACES.

Between the epidermis of the white and the coloured races there is a perfect identity of structure; the only difference is, that the young epidermic cells of whites contain little or no colouring matter, or pigment granules, except in certain situations, while those of blacks are filled with them; this difference can scarcely be regarded as permanent or structural; it is one rather of degree than kind, and over which, moreover, climate exerts an all-powerful influence.

We have continual opportunities of witnessing the effect of climate in increasing the amount of pigmentary matter in the skin. All have noticed that after a few years' residence in a hot country, the skin of many individuals becomes several shades darker than it was previously, and that even the inhabitants of the same country are darker during the summer than in winter.

It would appear, therefore, to be very possible, that climate alone, operating through many ages, would be sufficient to change the colour of the skin from white to all the varying shades of red, olive, and black, met with amongst the different families of the human race.

DESTRUCTION AND RENEWAL OF EPIDERMIS.

The epidermis, like the epithelium, is constantly undergoing destruction and renewal; the evidences of this are, however, more obvious and striking in the case of the epidermis, than were those adduced in proof of the destruction of the epithelium.

Thus the destruction of the epidermis is proved by a variety of facts: —

By the gradual disappearance from the skin of indelible stains, such as those produced by nitrate of silver or nitric acid.

By scraping the soles of the feet after immersion in warm water; the white and powdery material which is obtained, often in large quantities, examined with the microscope, will be found to consist of epidermic scales.

By the use of the warm bath; floating on the surface of the water will be observed more or less of a thin and whitish scum; this consists of desquamated epidermis.

By rubbing the moist skin with a rough towel; a considerable amount of epidermis visible to the naked eye will be removed.

The skin of new-born children is frequently observed to be covered with a white and soap-like crust; this, examined with the microscope, will be found to consist of epidermic scales mixed up with sebaceous matter.

The last proof to be adduced of the desquamation of the epidermis is one derived from disease; after inflammation of the skin, whether that of erysipelas, scarlatina or measles, the epidermis peels off, a new one being previously formed beneath the old.

Amongst many of the amphibia and reptiles, the casting of the epidermis is a periodical occurrence; in man, on the contrary, it is a constant and gradual process normally, although it is also occasionally periodic from disease.

USES OF THE EPIDERMIS.

The principal uses of the epidermis are threefold.

The first and chief use is to serve as a protection to the more delicate parts which lie immediately beneath it.

The second is to prevent the too rapid dissipation of the caloric of the system.

The third use has reference to secretion. It is evident, however, that the importance of the epidermis as a secreting organ is not considerable, seeing that the external surfaces of the body do not require to be kept moist, to the same extent as the internal. That the epidermis does not very actively administer to secretion might be inferred from the transparency of the fully developed cells, the faintness of the nuclei, and the paucity of the granules contained within them.

Epidermic cells are also capable of absorption, a fact which their change of colour after long immersion in water testifies.

By far the best description of the anatomy of the epidermis which has fallen under my notice is that contained in the admirable chapter on the Anatomy and Physiology of the Skin attached to the second edition of Mr. Wilson's work on the Diseases of the Skin.

Art. XI. THE NAILS.

The horny appendages of the feet and hands, the nails, do not constitute a distinct structure or type of organisation in themselves, but are merely modifications of one which has already been described, viz. the epidermis.

Nails, therefore, consist of cells similar to those of which the epidermis is itself constituted, with the difference, that they are harder, drier, more firmly adherent to each other, and that in the majority the nucleus is obliterated. (See Plate XXV.)

To display the cellular constitution of nails some little nicety is required; it may be shown, however, in the thin scrapings of any fragment of nail submitted to the microscope, as also by soaking the nail in a weak alkaline solution, and which, acting upon and dissolving the intercellular and uniting substance, sets free the cells.

The cellular structure of nails may also be shown, even without previous preparation, by a careful examination of the root and under surface of the nail, in which situations young and nucleated cells may usually be detected.

The younger nail cells, like those of the epidermis in the coloured races, contain pigmentary matter.

Nails, however, are not simply constituted of superimposed and adherent cells, but these are regularly disposed in layers or strata, each of which probably indicates a period of growth.

These layers, marked by striæ, may be clearly seen on any thin section of nail, whether longitudinal or transverse; they do not appear to follow any very definite course; usually in a longitudinal slice, they run from above downwards and forwards; sometimes they are horizontal, but I have seen instances in which the striæ were directed obliquely backwards, in place of forwards. In the transverse section, the striæ are less strongly marked, and run usually more horizontally. (See

Plate XXV.) Occasionally they are seen to pass in opposite directions, and to decussate. I am disposed to think that the one set of striæ visible are rather apparent than real, and are produced by the knife employed in making the section.

It is usually easy to distinguish the superior from the inferior edge of a slice of nail; the former will generally appear quite smooth, while the latter will be rough and uneven. (See Plate XXV.)

Such is a brief sketch of the structure of nails *: their form, position, and mode of connexion may next be considered.

Each nail may be said to be quadrilateral and convex from side to side, as it is also very generally from before backwards; the three posterior margins are received into a groove formed by a duplicature of the dermis and epidermis, the anterior margin alone being free. The root and sides of the nail, the former consisting of about one-fifth of its extent, are intimately attached to both surfaces of the groove; the inferior aspect of the body of the nail is likewise firmly adherent to the derm beneath it, except for a small distance at its anterior part.

The nail, then, is attached to the dermis by its root, and by a portion of its inferior surface; this attachment, however, is scarcely to be considered as structural, since it consists of a mere adaptation of the opposing surfaces of the dermis and nail. The surface of the dermis upon which the nail rests, it is known, is not smooth, but is raised into papillæ; to these the nail adapts itself, and in this way the two become intimately united.

It is in this manner, also, that the longitudinal lines observed on most nails are produced, and the appearance of which has induced some observers to entertain the idea that they are of a fibrous, and not a cellular constitution.

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* The first exact description of the nail and of the disposition of the derm which supports it was given by Albinus (Adnotat. Acad. lib. ii. 1755, p. 56.), but Schwann showed that the nail had a lamellated structure, and that the lamellæ are composed of epidermic scales. (Mikroskopische Untersuchungen, 1839, p. 90.)

Nails are, to a considerable extent, hygroscopic, becoming by the imbibition of fluid soft and yielding.

DEVELOPMENT OF NAILS.

Nails are developed somewhat differently from the epidermis of which we have stated that they are a modification; thus they do not increase by the equal development of new cells on the entire of their under surfaces, but they grow from a point, from the base or root of the nail.

The reality of this mode of development becomes evident from the following considerations: —

1st. That the younger nail cells are found principally at the root of the nail.

2nd. That if the relative situations of two spots or stains be observed, it will be seen that during the growth of the nail, they preserve precisely the same relation with each other, only that they gradually approach the end or free margin of the nail, which at length they reach, and from which finally they are worn away. This observation proves the absence of interstitial growth, and shows that the nail increases in length by additions made to the root.

Although it is certain that the longitudinal growth of nail occurs by the development of cells at the root, yet it is also evident that its thickness is increased by the formation of new cells on its under surface, where they may usually be detected with the microscope in a partially developed state. This double development explains why the nail is thinnest at the root, where only a single method of growth prevails.

The junction of the root with the body of the nail is indicated by a semicircular line, and the former is not merely thinner than the latter, but it is also softer and whiter; whiter in consequence of the subjacent dermis containing in that situation fewer blood-vessels, and its papillæ being smaller.

From the preceding account of the development of nails, it follows that when these sustain any loss of substance on their upper surfaces, this loss is never repaired, but remains without alteration until it reaches the free margin of the nail

Epithelium, epidermis, nails, and some other structures of the body, never seem to attain to a stationary state; they are throughout the whole of life undergoing a process of development; this in the case of the nails of man renders the interference of art necessary to remove from time to time the redundant growth.

It is probable, however, that if the nails were not cut, but allowed to grow at will, they would not exceed a certain length; amongst the Chinese, who do not pare their nails, they are usually about two inches long.

Nails doubtless sustain a loss of substance beyond that which they experience from occasional cutting, as from friction and the desquamation of the cells from the inferior and anterior portion of each nail, and which may be inferred to take place from the fact that the matter which accumulates beneath the extremities of the nails is to a great extent made up of epidermic or nail cells.

It has been estimated that the entire body of a nail, from the root to its free margin, is developed in from two to three months.

The third month of intra-uterine life is the earliest period at which the nails can be detected; they then consist of nucleated cells, and rather resemble soft epidermis than the hard and horny texture of fully developed nails.

A nail which has been once entirely destroyed is always regenerated in a very imperfect manner, it being usually seamy and irregular in consequence of the disturbance and injury sustained by the subjacent dermis, and the markings of which are impressed upon the nail.

Nails are subject to deformity in certain chronic maladies of the heart and lungs, especially in cyanosis and phthisis. It has been suggested that this may depend upon the state of the circulation in the vessels of the dermis.

The various modifications of nail met with throughout the animal kingdom, the claws of birds and carnivora, the hoofs and horns of ruminants, have essentially a similar structure to the nails of man. The hoof of the horse and of some other animals is traversed from above downwards by the spiral ducts of the sebaceous glands.

Art. XII. PIGMENT CELLS.

Colouring matter is found in the animal organisation in two states, either diffused throughout the fluid contents of colourless cells, as in fat cells generally, but especially in those of the iris of birds, and as in the liver cells, and red blood discs, or it is limited to the granules contained in certain peculiar cells, the parietes of which are also colourless, which have received the name of pigment cells, and which we are now about to describe.

Pigment cells have precisely the same structure as those of epithelium and epidermis, the description of which has just been brought to a conclusion; that is, they consist of cell wall, nucleus, cavity, and granules; the only difference between the two is, that the granules in the one case are coloured, and in the other colourless: as may be inferred from their similarity of organisation, a similar mode of development prevails in both.*

All the varieties of colour of the eye and of the skin observed amongst the different members and families of the human race depend upon the number of pigment cells and the shade and intensity of the colouring matter enclosed within the pigmentary granules; the deeper the colour, the more abundant the pigment cells, and the greater the depth of colouring contained in the granules; thus, of course, the pigment cells scattered beneath the epidermis of the Ethiopian are far more numerous than those found beneath that of the white race, and the colouring matter of the granules is doubtless also darker.

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* Mondini (Comment. Bonon, t. vii. 1791, p. 29.) was the first observer who made accurate microscopic observations on the pigment of the eye. He stated that the pigment is not simply mucus, but a true membrane formed of globules disposed in quincunx. The son all but completed the work which the parent began: he found that each globule is made up of little black points. Finally Kieser (De Anamorphosi Oculi, 1804, p. 34.), described the pigmentary membrane as a cellular tissue containing corpuscles.

In the white, however, a greater or less number of pigment cells is almost invariably found in certain situations, as in the eye, on the internal surface of the choroid, and the posterior aspect of the iris and ciliary processes, also between the sclerotic and choroid; in the skin at certain localities where it is placed beneath the dermis and epidermis, as in the areola round the nipples, especially of women, and about the perinæum and genital organs.

In the black races, pigment cells follow a similar distribution in the eye; but beneath the epidermis, as also under the nails, they form a continuous stratum composed of superimposed layers of cells.

There are yet other situations in which pigment cells have been encountered: thus Valentin * has signalised the occurrence of pigmentary ramifications in the cervical portion of the pia mater, to which they impart a blackness perceptible to the unaided sight.

Again, Wharton Jones † has described a thin but evident layer of brown pigment in the membranous labyrinth of the ear of man. It has been observed in other mammalia in which it is still more marked, in the same situation, by Scarpa, Comparetti, and Breschet. ‡

The brown spots, known by the name of freckles, with which the faces of most persons are more or less covered in summer, are due to a development of pigment cells.

A development of pigmentary matter frequently takes place as the consequence of disease; thus, it is of common occurrence to meet with growths either entirely or in part composed of pigment cells, the tumours, with the proper structure of which it usually thus intermingled, being those of cancer or medullary fungus.

The nature of the pigment-like matter found in the lungs

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* Verlauf und Enden der Nerven, p. 43.

† Article HEARING in the Cyclopædia of Anatomy and Physiology, t. ii. p. 529.

‡ Récherches sur l'Organe de l'Ouïe de l'Homme, Paris, 1836, in 4to.

and bronchial glands of aged persons and animals has been the subject of much discussion; nor has it been as yet decided whether it be true pigment, or merely a deposition of carbon. Pearson * maintained the opinion that the colouring matter is the powder of carbon, since neither chlorine nor the mineral acids act upon it.

In those remarkable *luces naturæ,* Albinoes, there would appear to be an absence of pigmentary granules in all parts of the body, even in the eye: the pigment cells themselves are stated to exist, but to be wanting in their characteristic coloured contents.

Pigment cells do not present the same size, form, and character wherever they are encountered.

Thus those of the choroid are adherent, large, flattened, polygonal, mostly hexagonal, with clear nuclei and margins; occasionally, however, it happens that both nuclei and cell wall are obscured by the number and disposition of the contained granules: the cells are mostly of uniform size as well as shape, in consequence of which regularity they form a very beautiful microscopic object; sometimes, however, one cell is observed to be larger than the rest, octagonal, and surrounded by a number of cells of smaller size than ordinary, and mostly pentagonal.

According to Henle †, the contained granules are situated in the posterior part of each cell, while the nucleus is placed in its anterior division; it is this arrangement which allows of the nucleus being so clearly seen; in those cases, however, in which the nucleus is obscured, acetic acid will frequently bring it into view; this, if concentrated, will dissolve the cell wall, set free the granules, and leave the nucleus.

Schwann states that he has seen the pigmentary granules in the cells of the choroid in active motion.

The cells of the choroid form by their adherence a membrane resembling the most regular and beautiful mosaic pavement in miniature.

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* Philosophical Transactions, 1813, pl. ii. p. 159.

† Anat. Gen. vol. vi. p. 295.

The pigment cells of the posterior face of the iris and ciliary processes are smaller than those of the choroid, are for the most part round, or approach that form, and so filled with corpuscles that the nucleus and margin of the cell is not usually visible.

In the skin the pigment cells are placed between the dermis and epidermis; they do not there form a layer of equal thickness, but accumulate in the depressions left between the papillæ, forming many superimposed layers, while on these they are spread out in a single thin layer, and are often much scattered. It is to this circumstance, as well as the thickness of the epidermis, and the state of repletion of the cells, that the varying shades of the colour of the skin of the same individual depend. In the negro the cells resemble much in form those of the choroid, being either perfectly hexagonal, polygonal, or irregularly rounded; the nucleus can be well seen in those cells which are less filled.

Amongst the white race, the pigment cells in those situations in which they occur beneath the skin are fewer in number, smaller, more rounded, and frequently resemble little masses of corpuscles rather than distinct cells; nevertheless it is even here sometimes possible to distinguish the nucleus and cell wall.

There exists between the internal face of the sclerotic and the external of the choroid a fibrous tissue of a brown colour; this, when these two coats of the eye are separated, remains attached in part to the one and in part to the other; that, however, which adheres to the sclerotic has received a distinct name, and is called *lamina fusca*. Now the colour of this layer is due to the presence, scattered amongst the fibres, of pigment cells of a very peculiar form and construction; they are mostly very irregular in size and shape, are marked with a clear central spot, which indicates the locality of the nucleus, and from the margin of many of them proceed filamentous processes of variable number and size, and the extreme points of which are mostly colourless, and are not dissolved by acetic acid.

Pigment cells of analogous construction exist on the external surface of the choroid, and also on the cervical portion of the pia mater.

Mixed up with perfect pigment cells a greater or less number of pigment granules are always observed; these are amongst the smallest objects in nature, and, on account of their minuteness, it is in them that molecular action in all its activity is best seen: they are not spherical in form, but are flattened, so that they appear as discs, lines, or points, according as the surface, side, or end presents itself to the eye of the observer.

It is probable that it is by means of these granules that pigment cells are multiplied.

Climate, and particular states of the system, as pregnancy, have much effect in increasing the amount of pigmentary matter beneath the skin; from the latter cause the areolæ around the nipples frequently become of a deep chocolate colour. Of the influence of the former it is scarcely necessary to cite examples: it may be remarked, however, that freckles are due to the development of pigment cells, brought about by the action of the summer's sun.

This augmented development of pigment cells may be rationally explained by the increased determination of blood to the dermis of the breast from increased activity of function in that organ during pregnancy, and to the general surface from the effect of the sun's heat.

It is questionable whether all the varieties of colour of the human species have not originated in climateric causes, operating through many ages.

It may also be questioned whether pigment cells are not susceptible of being developed into those of the epidermis. If the epidermis of a negro, raised from the surface by means of a vesicatory, be examined with the microscope, it will be noticed that the most external cells contain a considerable amount of colouring matter, which, as this resides in solid granules and not in a fluid, it is difficult to suppose had entered the cells by endosmosis.

Pigment cells are capable of regeneration in a part in which they have been destroyed: it is necessary, however, that the subjacent dermis be not too deeply injured; the cicatrices remain for a considerable time nevertheless without colour.

The skin of the children of negro women does not acquire its full depth of colouring for some days after birth.

Pigment cells are developed at a very early period of intra-uterine life. The uses of pigment in the skin are not well understood; that in the eye is doubtless of importance in the discharge of the functions of that organ: it is known that the Albinoes, in whom it is either absent or exists but in small quantities, are incapable of supporting a strong light.

Pigment cells of particular forms occur amongst some of the lower animals. Those of the internal surface of the choroid of fishes and birds, situated in front of the ordinary coloured cells, have the form either of short sticks or clubs. The argentine pigment of the iris and peritoneum of fishes is composed of elongated corpuscles. The pigment cells placed beneath the epidermis of the frog are for the most part stellate.

ART. XIII. HAIR.

WE now come to the description of another epidermic modification, viz. hairs: these, however, are much more complex in their structure than any which have been hitherto described, and are less obviously derived from the epidermis.

As in the case of most of the solids described in this work, we shall first discuss the different particulars relating to form and size, and next proceed to the description of structure.

FORM OF HAIRS.

Hairs consist of two parts, a root and a stem: in speaking of the form of hairs, reference is made to the latter. Hairs then are elongated, and more or less cylindrical developments of the epidermis. They depart, however, in most cases from the character of a true cylinder in two respects; first, they are not perfectly spherical, but are seen to be, when viewed transversely, either oval, flattened, or reniform (see Plate XXIX.); and secondly, they are not of equal diameter throughout, being thickest at about the junction of the lower and middle thirds of the stem, of smaller diameter from this part downwards towards the root, and still more reduced in size as the free extremity is approached, and which, in a hair which has not been recently cut, terminates in a point, the diameter of which is frequently several times less than that of the more central parts of the shaft. (See Plate XXIX.)

This form is best seen in hairs of medium length, as those of the whiskers, eyebrows, axillæ, and pubis, in which also the flattened and oval shapes are principally detected.

The hairs which approach most closely the cylindrical are those of the scalp, Henle * makes the interesting statement, that the curling of hair depends upon its form, and that the flatter the hair, the more it curls, the flat sides being directed exactly towards the curve described. From this it follows, that the hair of Negroes would exhibit in a very marked manner this flattened form.

SIZE OF HAIRS.

Hairs differ remarkably in size, both as regards length and breadth: they differ not merely in different individuals, in different localities in the same person, but also in any one given situation, as the scalp or pubis.

The hairs of the scalp are the longest; those of the scalp of women are many times longer than those of the same part in man, and according to the measurements of Mr. Wilson, they are also thicker. Next in length come the hairs of the chin of man. Amongst women, instances have been known of the hair extending from the scalp to below the feet, and the beard of man not unfrequently reaches to the waist.

The shortest and smallest hairs are those covering the general surface of the body, and which are reduced to mere down (lanugo).

The thickest hairs of the body are those of the whiskers, chin, pubis, and axillæ, the finest those distributed over the general surface; the hairs of the scalp are of intermediate diameter.

The hairs of children are finer than those of adults, and those of the head of men than those of women.

It cannot be doubted but that frequent cutting and shaving of the hair tends to increase its thickness.

STRUCTURE OF HAIR.

Each hair admits of division into two parts, the root and stem, and each of these, again, allows of still further sub-

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* Anat. Gen., vol. vi. p. 314.

division: thus the root consists of the prolongation of the hair proper, or stem, terminating in an expanded portion which has been termed the bulb, and of a double sheath; the stem also is divisible into cortex, medulla, and intervening fibrous portion, which constitutes the chief bulk of the hair. (See Plates XXVIII. and XXIX.)

These divisions of the root and stem of hairs suggest its comparison to a tree, the stem of which also resolves itself into cortex, medulla and intervening woody or fibrous substance. The comparison is also heightened by the similar relation in which both stand to the parts around them, viz. the soil in the case of the tree, and the dermis in that of the hair.

Root of Hair.

We will first describe the root, because it is the source from which the hair is developed: this, as already noticed, consists of two parts, the sheath and the bulb.

The Bulb. — The bulb is the expanded and basal portion of the stem of each hair: it is usually two or three times the diameter of the hair itself, and is sometimes excavated below: it is constituted of granular cells, which are either circular, angular, or elongated in form, the spherical cells, form the extremity of the bulb, the polygonal ones its surface, and the elongated cells are placed above the spherical ones, of which they are modifications, and beneath the angular cells of the surface of the bulb. Acetic acid will be found useful in displaying the cellular structure of the bulb.

In healthy hairs this bulbous portion of the stem is always coloured, which is not the case with grey hairs. (See Plate XXVIII.)

The part of the stem of the hair immediately above the bulb, and included within its sheath, exhibits the structure of the body of the stem itself, being divisible into scaly cortex, fibrous intervening substance, and granular medulla.

Sheath. — The bulb and lower portion of the stem of the hair is included in a sheath consisting of two distinct layers, an outer and an inner. (See Plate XXVIII. *fig.* 1.)

The *outer* layer is an *inversion* of the epidermis: it first merely encircles the portion of the stem of the hair beneath the level of the epidermis: it next surrounds the inner layer of the sheath, to which it soon becomes intimately adherent; finally, it forms a *cul de sac* around the bulb of the hair.

The fact of the inverted sheath of the epidermis forming a pouch around the bulb of the hair, may be inferred from the circumstance, that when the epidermis peels off as the result of decomposition, the hairs usually come away entire with it; its continuation moreover around the bulb may be shown in transverse sections of the skin of the axillæ and whiskers, in which the hairs penetrate into the subcutaneous fatty substance. (See Plate XXVIII. *fig.* 1.)

This outer layer is colourless, is possessed of considerable thickness, and is evidently made up of granular cells similar to young epidermic cells.

In most hairs, whether coloured or uncoloured, which have been forcibly removed from the skin, this outer layer is usually torn across, the rupture occurring almost invariably at a little distance from the bulb of the hair: the root of the hair then below this breach of continuity consists only of the inner layer of the sheath and of the stem of the hair; and at this situation, the root to the naked eye appears contracted: this is, however, but an appearance, the result of the absence of the outer layer, and of the expansion of the stem into the bulb. (See Plate XXVIII. *fig.* 2.)

The *inner* layer of the sheath is an *eversion* or revolution of the epidermis, and is an offset or continuation of the outer layer, commencing at the lower part of the bulb: it is colourless, possessed of considerable thickness, its diameter being about one-third of that of the stem of the hair in its thickest part: it tears readily in the longitudinal direction with a somewhat uneven fracture; and hence may be inferred to be of a fibrous constitution, as may be shown to be the case: its inner surface is marked with reticulated lines, the impressions of the cortical scales of the shaft of the hair.

This inner layer is not of equal diameter throughout, but tapers gradually from below upwards: it is well defined both internally and externally, except where it comes in contact with the bulb internally, with which its inner edge or surface becomes incorporated; above it terminates in a thin border at a little distance below the level of the skin. (See Plate XXVIII. *fig.* 1.)

The outer layer, although adherent to the inner at its lower part, does not become incorporated with it: the latter, except at the point indicated, preserves everywhere its independence and individuality. The two layers, it will thus be seen, might with much convenience have been described, as two distinct sheaths, an inner and an outer: to do so, would be, however, to lose sight in some measure of the similar origin and nature of the two.

In the fact, however, of the inner sheath exhibiting a fibrous structure, and of its incorporation with the bulb, it would appear to have more structural affinity with the fibrous portion of the stem of the hair itself than with the outer layer or cellular sheath.

This inner layer might be appropriately termed the "*modelling sheath*," since it doubtless regulates the form and dimensions of the shaft of the hair, the substance of which when first developed is soft and plastic. Henle describes the inner layer as fenestrated: this structure I have never seen exhibited.

Shaft of the Hair.

The stem or shaft of the hair is divisible, as already observed, into cortical, medullary, and fibrous portions.

Cortex. The cortical part of the hair consists of a layer of scales, imbricated upon each other after the manner of tiles upon the roof of a house. (See Plate XXIX.) These scales are best seen in the larger hairs of the whiskers and pubis, and in the small downy hairs; they are smaller than the ordinary cells of epidermis, and are rarely seen to be nucleated. Maceration of the hair in sulphuric acid causes them to fall off, and in this way their size, form, and structure, may be satisfactorily studied.

The scales are absent from the points of the finer hairs. In consequence of their imbrication upon each other, their little thickness, and of the double contour presented by their free edges, they frequently convey the appearance rather of anastomosing fibres running round the hair than of distinct scales.

A hair rolled between the fingers always advances in a given direction, viz. towards the apex: this results in part from the tapering form of the hair, and partly from the more or less spiral disposition of the scales.

Fibrous Layer. — The fibrous portion of the stem of the hair constitutes its chief substance and bulk, forming two-thirds of the entire diameter, one-third on each side of the medulla. In hairs which are not too dark, the constituent fibres may be seen *in situ:* they are most palpably brought into view either by scraping the hair with a knife or by crushing it after maceration in sulphuric acid: they are also best seen in the larger hairs and near the centre of the shaft.

Henle describes the fibres as flat, with uneven edges, and is in doubt as to whether they are branched or not. To my observation they appear much smaller than they are stated to be by Henle, and are spherical and simple. (See Plate XXIX.)

These fibres have a cellular origin, and are formed by the elongation of the inner cells of the bulb in which their gradual extension into perfect fibres may be traced.

They are stated by most observers not to extend to the extreme point of the hair; and the same statement is likewise made in reference to the medullary canal and cortical scales. Of what, then, it may be fairly asked, is the point of the hair constituted, since every structure entering into the formation of the shaft is denied to it? The assertion that the fibres do not extend to and form the apex of the hair is evidently erroneous. In the examination of the points of a number of hairs which have not been recently cut, fibres often separated from each other and loose will frequently be detected. (See Plate XXIX.)

The whole of the fibres of the stem, however, do not extend its entire length, the majority terminating long before the extremity is attained; and it is to this fact that the attenuated form of the hair is attributable. In some hairs the fibres are seen to terminate at regular distances, their points describing transverse lines on the stem of the hair.

The splitting, of such common occurrence in hairs which are allowed to attain an excessive length, is due to a separation of the fibres from each other.

The fibrous portion in young and healthy hairs is coloured.

Medullary Canal and Medulla. — In most hairs which are not of too deep a colour a medullary canal may be detected running up the centre. This commences in the upper portion of the bulb, runs along the shaft, but ceases as it approaches the apex: its diameter varies with that of the hair itself, but usually bears the proportion of a third of its thickness. (See Plates XXVIII. and XXIX.)

Henle is uncertain whether this canal is lined by a distinct membrane or not, but inclines to the opinion that it is so.

The medulla or contents of this canal exhibit a granular appearance, and are made up of pigment granules, a few perfect pigmentary cells, and particles of coloured oil: it is therefore in the medulla that the greatest amount of colouring matter of the hair is situated. (See Plate XXVIII. *fig.* 1.)

At the very commencement in the bulb of the hair the medulla has distinctly a cellular origin.

In young and healthy hairs it is also continuous throughout the entire extent of the medullary canal; in old and discoloured hairs, on the contrary, its continuity is frequently interrupted by distinct intervals, and it only partially fills the cavity of the canal even where it is present.

The medullary canal and medulla is best seen in the larger hairs, which are not of too deep a colour, and in grey hairs: in the fine and downy hairs of the general surface of the body, the canal and its contents, as a necessary consequence, are almost entirely absent.

In some rare instances two medullary canals have been observed in the same hair. In the sable the medulla has a distinctly cellular structure throughout.*

FOLLICLE OF THE HAIR.

Each hair is implanted in a distinct depression in the dermis, the base of which especially is freely supplied with nutrient vessels: this depression is also lined by an invagination of the epidermis, and which becomes ultimately the outer layer of the sheath of the root of the hair as already described. (See Plate XXVI. *fig.* 3.)

Between this layer, however, and the shaft of the hair for a short distance before it rises above the level of the skin, a space, or cavity is left, into this space the canals of one or more sebacious ducts generally open, and in it also entozoa frequently develope themselves.

It sometimes happens that two or more hairs are contained in the same follicle (see Plate XXVI. *fig.* 3.): in these cases, however, each hair has a distinct modelling sheath. In some animals the location of a number of hairs in one sheath is the ordinary mode of arrangement; in the pig, for example, the hairs are usually thus associated in threes, as also occasionally in man.

The hair follicle or crypt is best seen by examining thin vertical slices of the skin.

The length of the hair follicle and the consequent depth of implantation of the hair varies, but is often equal to the twelfth or sixteenth of an inch; the hairs of the head, of the whiskers, of the pubis, and of the axillæ penetrate into the subcutaneous cellular tissue; those of the eyelids and ears to the subjacent cartilages: the roots of hairs in general, however, do not penetrate beyond one half the depth of the corium, in the substance of which they are buried.

It is usually stated that the bottom of the follicle is occupied by a papilla furnished with blood vessels and nerves, on which the bulb of the hair immediately rests; and that it is owing to this papilla that the base of the bulb, when removed, exhibits a concavity. This description, in the case of tactile hairs, may be correct, but is surely not so when applied to hairs in general. Each hair does indeed rest upon a papilla, but it is one which is destitute of blood vessels and nerves, and which is cut off from all direct vascular communication by the *cul-de-sac* formed by the outer lamina of the sheath. This papilla may be described as a compound cellular vesicle, and is probably the true germ of the hair; it is on it that the bulb of the hair is situated, and which occasions the depression which this generally displays when it has been forcibly extracted. This germ is best seen in grey and light coloured hairs.

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* The first accurate observations on hair were made by Hook, Micographia, 1667, Obs. 32. tab. v. fig. 2., and Leeuwenhoek, Opera, t. iv. p. 46.

GROWTH OF HAIR.

The growth of hair takes place at the root, and is the effect of the development of new cells which is continually in progress in the bulb, and which afterwards become modified into those of the scaly cortex and fibrous stem; these new cells, coming behind the older ones, continually press them forwards, and thus occasion the elongation of the hair.

But the elongation of each hair takes place in a manner very different from that just mentioned, not from the development of new cells, but by the gradual elongation and extension of the cells already formed after they have quitted the bulb, and when they come to form the shaft of the hair. This mode of elongation, it can scarcely be called development, is proved by the gradual tapering of the hair which takes place after the point has been removed: of the truth of this fact not the slightest doubt can be entertained.

At the period of puberty a growth of hair takes place in certain situations in which previously it was not apparent, as on the chin, cheeks, in the axillæ, and on the pubis, abdomen, and chest; this development is an effect of the great functional activity which exists at that period, and which is the occasion of the increased and rapid growth of the several constituents of the body which then takes place.

The earliest periods at which the rudiments of hairs in the human fœtus have been observed is from the third to the fourth month: the hair follicle is formed in the first place, next the bulb, and then the sheath and stem of the hair, which, in the early period of its development, is curved upon itself.

Hairs are occasionally developed in certain peculiar situations, as on the mucous membrane of the conjunctiva, the intestines, and gall bladder, in the ovaries, and in steatomatous and encysted tumours.

Hairs may be transplanted, and, it is said, will grow after such transplantation in consequence of the adhesions and organic connexion established between them and the adjacent tissues,—a fact of which practical advantage might be taken if correct.

When a hair has obtained the full term of its development, according to the researches of Eble, it becomes contracted just above the bulb: this change probably announces its death and approaching fall.

REGENERATION OF HAIRS.

Hairs are peculiarly susceptible of being affected by the condition of the health, even more so than the epidermis. If this be vigorous, as a rule to which there are many exceptions, it will be found that the hairs themselves are thick and firmly set in the skin: if, on the contrary, the powers of the system be debilitated from any cause, the hair will either fall off spontaneously, or a very slight degree of force will serve to dislodge them from their connexions.

If the bases of those hairs which fall out of themselves be examined, or which are removed by combing and brushing, it will be seen that the bulb alone has come away, the entire sheath and germ remaining behind. In such cases the hair is doubtless regenerated, and after its regeneration is usually stronger than it was previously. (See Plate XXIX.)

It has not yet been ascertained by positive experiment whether the hair is capable of reformation in those instancss in which both bulb and sheath have been removed: it is most probable, however, that where they have been entirely abstracted, no renewal of the hair could ensue.

It is possible that in some cases the apparent regeneration of the hair arises, not from the development of new hairs in the primitive sheaths and upon the old germs, but from the formation of new hair follicles and germs: of this, however, no proof has as yet been given.

That a regeneration of new shafts of hair is continually in progress, whether from new germs or the older ones is not known, is proved by the detection of small and pointed hairs just emerging from the skin in the scalp of even old persons.

NUTRITION OF HAIR.

Hairs are nourished in the same way as the epidermis itself; that is, they do not receive into their own structure either blood vessels or nerves, but derive their nutriment from vessels which are so distributed as to come into close contact with the tissues to be nourished.

This indirect reception of the nutrient plasma explains the very great susceptibility of the epidermis and its several modifications to be influenced by causes affecting the general health, and in consequence the circulation and the qualities of the circulating fluid.

The epidermic tissues being placed in situations the most remote from the centre of the circulation, are endowed with but a feeble degree of vitality, and which is readily destroyed by causes affecting the amount and nature of the circulating fluid received by them.

The nutrient vessels and sentient nerves of each hair are distributed around and outside the sheath, and not in a raised papilla as generally described, although this may really be the case in the large hairs of the whiskers of some animals, as, for example, the tactile hairs of the seal, &c. The fact of the hair usually penetrating below the level of the true skin and into the subcutaneous fatty tissue seems to disprove the notion of a distinct and vascular papilla.

DISTRIBUTION OF HAIRS.

Hairs are distributed over the entire surface of the body, with the exception of the palms of the hands, soles of the feet, and last phalanx of the toes and fingers: there are, however, situations in which they are developed in increased quantities, as on the integument of the scalp, on that of the eyebrows, on the margins of the ciliary cartilages, and after the period of puberty, on the chin, cheeks, axilla, pubis, abdomen, chest, and at the entrance of the nares and ears.

The number of hairs found in these several situations differs very considerably in different individuals, according to age and condition of health.

Individuals of the male sex also are generally more hairy than females, in whom also no development of hairs takes place on the chin, cheeks, chest, and abdomen.

Of the number of hairs which exist on the entire surface of the body, some idea may be formed from the measurements of Withof. The quarter of a square inch furnished 293 hairs at the synciput, at the chin 39, at the pubis 34, on the forearm 23, at the external border of the back of the hand 19, and on the anterior surface of the thigh 13. Upon the same extent of surface Withof counted 147 black hairs, 162 brown, and 182 flaxen.

Hairs of great length and strength are often developed in considerable quantities in different parts of the body, in moles and nævi.

DIRECTION OF HAIR.

The hair follicles are not placed vertically in the skin, but obliquely, and the hairs which issue from them consequently themselves run in the same oblique direction. (See Plate XXVI. *fig.* 3.)

The apertures of most of the follicles look downwards, and hence we find in most cases that the points of the hairs, when fully developed, are similarly directed.

In addition, however, to this general arrangement and distribution, it will be seen that in early life the hair follicles are disposed in lines, the apex of one follicle nearly touching the base of the next: the lines thus described are not straight, but are more or less curved, and divergent or convergent after the manner of the lines upon the case of an engine-turned watch: the hairs which issue from the follicles thus take particular and determinate sweeps, which it is unnecessary to describe in detail.

It occasionally happens from some cause or other that the hair follicles are implanted in a manner the reverse of that which should obtain: this is especially seen in those of the scalp of children, in whom frequently certain tufts of hair grow up, and incline in a direction opposed to that of the contiguous hair. This mal-disposition of the hair is the source of much trouble and annoyance to anxious nurses and mothers, who spend much time in endeavouring to bring the refractory lock into order.

In this endeavour there can be no question but that it is possible to succeed, as is proved by the very different arrangement which the hair of the head is made to follow in accordance with the manner in which it is dressed.

ERECTION OF HAIR.

Man, to a certain extent, and many animals in a considerable degree, possess the power of erecting the hairs. This power in man is limited to the hairs of the head, in many animals it is much more general.

Most persons on sudden exposure to cold, and on experiencing of any emotion of fear or horror, feel a creeping sensation pass over the head: this sensation is accompanied by a certain degree of erection of the hair, but not indeed to such an extent as to cause it "to stand an end." Now this erection is the result of the distribution of fibres of elastic and contractile tissue throughout the substance of the corium, and which interlacing amongst the hair follicles, occasion the erection of the hairs themselves.

The distribution of these fibres, and their connexion with the bases of the hairs, are well seen in the skin of the hog.

COLOUR OF HAIR.

The colour of the hair depends upon the same cause as that of the skin and eye, and is due to the presence of pigment granules and cells; these are contained principally in the medullary canal, but are also interspersed between the fibres of the stem; they first become manifest in the upper portion of the bulb of the hair.

The depth of the colour of the hair very generally bears a relation to the development of pigmentary matter in other parts of the system, as in the eye and beneath the skin. To this rule, however, some remarkable exceptions are occasionally encountered.

The colour of the lighter hairs, as the red and flaxen, would appear to depend less upon the number and depth of colouring of the pigment cells and granules, than upon the presence of minute globules of a coloured oil.

In the hair of Albinoes but little colouring matter is present, and in grey hairs also, the colour has deserted the pigment cells and granules.

Hair is decolorised by long contact with chlorine.

It is generally stated as an undoubted fact, that the hair may turn white or become colourless under the influence of strong and depressing mental emotions in the course of a single night. This singular change, if it does ever occur in the short space of time referred to, can only be the result of the transmission of a fluid possessing strong bleaching properties along the entire length of the hair, and which is secreted in certain peculiar states of the mind.

GREY HAIR.

If a grey hair be contrasted with an unaltered one from the head of the same person, the following differences will be noticed between the two. The grey or white hair will be observed to be almost colourless, the bulb and fibrous portion will be destitute of colour, the medulla alone retaining a slight degree of coloration: this, however, is collapsed, and in place of being continuous throughout its length, will be seen to be interrupted at intervals. (See Plate XXVIII. *fig.* 2.)

The unaltered hair, on the contrary, is distinguished by characters the reverse of those exhibited by the grey hair; thus the bulb, stem and medulla are all deeply coloured, and the latter fills the entire cavity of the medullary canal, and is continuous throughout. (See Plate XXVIII. *fig.* 1.)

Grey hair retains a considerable degree of vitality, as is proved by its growth continuing for many years after its loss of colour.

PROPERTIES OF HAIR.

Hairs are remarkable for their strength, their elasticity, durability, and for the difficulty with which they undergo the process of decomposition: their strength results probably from their fibrous constitution; in their elasticity and durability, they partake of the character of all horny structures.

The strength of hair is proved by the fact that a single hair will bear a weight of 1150 grains.

Its elasticity is shown by the readiness with which each hair, when extended, returns to its original size and shape, as well as by the fact that the numerous hairs forming a curl or lock will recover their ordinary form and disposition after extension.

Its durability is shown by the persistence of hairs throughout many years of life.

Lastly, its indestructibility is proved by the occurrence of hairs in the tombs of persons buried for ages.

A hair, however, which has been very forcibly extended will not return to quite its original length, but will remain a certain degree longer than it was previous to the extension. A hair may be extended a third of its length without breaking; elongated a fifth, it remains a seventeenth longer than it was before; it continues a tenth longer after having been extended a fourth, and a sixth only after having been drawn out as much as possible.

Hairs, when they are dry, become electrical by rubbing and emit sparks: this is well known with respect to the coat of the cat, and Eble has observed the same thing to occur in man.

Hairs are also eminently hygroscopic, and imbibe moisture from the air and from the skin, in consequence of which they lose their set or curl, and become flaccid and straight.

Nitrate of silver blackens the hair, a sulphuret of silver being formed, and it is of this ingredient that the majority of hair dyes are chiefly constituted. The concentrated mineral aicds, especially the nitric, dissolve the hair, as does also caustic potash.

When heated hairs take fire and burn with a fuliginous flame, emitting the odour of bone, and leaving a residue of carbon. To dry distillation, they yield a quarter of their weight of carbon, which is difficult to incinerate, the products being empyreumatic oil, water charged with ammonia, and combustible gases, which comprise sulphureted hydrogen. The ashes contain oxide of iron, traces of oxide of manganese and silica, and of sulphate, phosphate, and carbonate of lime.

THE HAIRS OF DIFFERENT ANIMALS.

The precise structure of the hairs of different animals varies considerably: those of the mammalia resemble the hairs of man, or differ only in the degree of their development, as the whiskers of the carnivora and rodents, and manes and tails of horses, the bristles of pigs, &c.: it is in these largely developed hairs that the structure can be best determined: thus in the majority of them it is stated to be easy to detect the vessels and nerves of the papillæ on which the bulb rests, and which penetrate into it: nerves have been detected by Eble in the cat *, by Rapp in the seal, porcupine, and many other animals †, and by Gerber in the pig. ‡

In the hairs of the musk deer there seems to be no separation of parts into scaly cortex, fibres and medulla, the entire hair being uniformly cellular.

In that of the sable the fibrous portion is absent, and there is only scaly cortex and cellular medulla.

In the hairs of most rodents the medulla is divided by dissepiments, and in other animals, as the sable, it is composed of large and distinct cells.

The hairs of the mouse, bat, and martin are branched or knotted.

In the spines of the porcupine and hedgehog the inner bark penetrates in longitudinal bands into the cavity of the medullary canal, and thus divides the medulla itself into incomplete segments; the transverse view of such spines represent a starred or rayed figure.

In birds, hairs are replaced by feathers, which are to be regarded as modified hairs.

THE USES OF HAIR.

The uses of hair are manifold.

In certain situations, as on the head, it is to be regarded as an ornament.

In other localities, as on the cheeks and chin, it imparts character and expression to the face.

In others again, as on the pubis and about the genital organs, it serves the purpose of concealment.

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* Von den Haaren, t. 11. p. 19.

† Verrichtangen des freuften Nervenpaares, p. 13.

‡ Allgemeine Anatomie, p. 79.

The general use of hair wherever encountered, it being a non-conductor of caloric, is to preserve the warmth of the system.

Those situated at the entrance of the nares and meatus auditorius externus are placed there to prevent the entrance of foreign bodies, insects, &c.

It is difficult to assign any use to the hairs of the axillæ.

It is very probable that hairs have other uses, and that they exert some influence in regulating the electric condition of the body.

ART. XIV. CARTILAGES.

CARTILAGES are amongst the most solid structures entering into the constitution of the animal organization; they are, however, not less remarkable for their elasticity and flexibility than for their solidity.

The essential element of the several fluids and solids hitherto described in the course of this work we have seen to be cells: this cellular composition is exhibited in a high degree by cartilages.

The texture and colour of the cartilaginous tissue varies considerably: it presents either a white or bluish white, semi-transparent and homogeneous appearance, or it is yellow, and exhibits a fibrous texture.

These differences of texture and of colour indicate a difference of structure, upon which a division of cartilages into the true and fibro-cartilages has been based.

TRUE CARTILAGES.

True cartilages consist of cells, contained in cavities, which are themselves formed in a solid and hyaline intercellular substance.

They comprise all those cartilages which cover the articular extremities of the bones (that of the glenoid fossa and of the head of the inferior maxilla alone excepted), the cartilages of the entire respiratory apparatus (with the exception of the epiglottis and the cuneiform cartilages), those cartilages which are to a considerable extent free and independent, and which have been denominated *figured* cartilages, as those of the ribs, the ensiform cartilage; the trochlea of the eye, the nasal cartilages, and the *Corpuscula triticea* in the lateral hyo-thyroid ligaments. (See Plate XXX. *figs.* 1 and 2.)

The true cartilages are distinguished from the fibro-cartilages by their bluish and transparent aspect.

Structure of True Cartilages.

True cartilages consist, as already mentioned, of hyaline matrix, cavities, and cells; each of these constituents will be described in succession.

Hyaline Matrix. — The intercellular substance, or hyaline matrix, although it does not usually present any distinct traces of organization, yet contains, scattered through it, numerous granules of different sizes, and many of which are to be regarded as the cytoblasts from which new cells are continually being developed.

The amount of this intercellular substance varies in different cartilages, and is greater in fully developed than in very young cartilage.

Cavities. — The cavities of true cartilages vary both in size and form; in shape they are irregular, although for the most part elongated.

They are, in most cases, to be regarded as simple excavations or fossæ in the hyaline matrix; in others, however, it would appear from the observations of Henle *, Bruns †, and Schwann ‡, that they are lined by a distinct membrane, and which is indicated by a double contour, by the difficulty experienced in setting free the contained cells, and by the fact, that by boiling, the intercellular substance is dissolved, while the cavities remain as distinct corpuscles.

Such cavities would stand in the relation of parent cells to those which they include.

Cells. — The cells of cartilages are very different from those occurring elsewhere in the animal organization; they are distinct in their form and in the character of their contents.

Cartilage cells, like the cavities in which they are enclosed, are irregular in size and shape; they are, however, generally elongated, sometimes flattened and compressed; at others, they are perfectly spherical: these several shapes depend upon the degree of pressure to which the cells are subject, and which is greatest at the free margins of the cartilages where the compressed form occurs, and least in the centre where the spherical cells are chiefly encountered. Each cell contains a nucleus which is either smooth or granular; it includes also very generally one or more shining and globular bodies of an oleaginous or fatty nature, and which, in many cases, are to be regarded as transformed nuclei.

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* Anat. Gen., vol. vii. p. 364.

† Allg. Anat., p. 215.

‡ Mikrosk Untersuch.

The cells usually lie as it were scattered irregularly throughout the intercellular substance; in some cases, however, they are arranged in definite order; thus in the condensed margin of all the true cartilages the cells are compressed, and lie with their long axes disposed parallel to the surface. (See Plate XXX. *fig.* 1.) Again, in the ribs, they radiate in straight lines from the centre towards the circumference: this disposition of them accounts for the fibrous fracture which they exhibit when broken across, as also for the fact of their being divisible into thin transverse layers. The linear arrangement of the cells in the fully developed cartilages of the ribs is very frequently not perceptible.

In very thin cartilaginous laminæ, as those forming the alæ of the nose, the difference in the form of the central and periphral cells does not exist, the entire intercellular substance being filled with small and rounded cells.

The cells usually occur singly in the hyaline matrix; they are, however, frequently encountered in groups of two, three, or four cells, each of which is distinct, and describes a more or less regular segment of a circle: this disposition of the cells is connected with their mode of multiplication, as will be seen hereafter.

Again, groups of *secondary* cells sometimes occur especially in the intervertebral fibro-cartilages, included in the membrane of the primary or parent cell. (See Plate XXXI.)

Moreover, Henle [*] has noticed a peculiar arrangement of

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[*] Anat. Gen., vol. vii. p. 366.

the cells of the cartilages which cover the articulating surfaces of the larger bones. On the free surface the cells are as in most cartilages small, flattened, and disposed horizontally; the deeper seated cells become larger and longer; their axes, on the contrary, being directed either vertically or obliquely to the surface; sometimes also the cells although separated by distinct intervals, are arranged the one above the other in such a manner as that the superior appears to be a continuation of the inferior; at others an inferior cell appears to divide into two others, placed above it, and thus represents a bifurcation. Henle also states, that he has seen not unfrequently the outline of a cavity prolonged from one longitudinal series of cells to a neighbouring series. It is very possible, Henle goes on to observe, that these cavities form part of a system of elongated canals, which taking an undulous course, and sometimes bifurcating, traverse the cartilage from its inferior to its superior surface, and which, when one makes a section, are divided into two portions, the one remaining in one segment, the other in the other segment. This structure, he proceeds to remark, explains sufficiently why articular cartilages exhibit a fibrous fracture, and why the earlier observers believed them to be composed of fibres which ran perpendicularly to the thickness.

This ingenious notion of Henle, although it serves to account for some hitherto unexplained phenomena connected with the articular cartilages, is yet of very doubtful application even to them, and certainly no such arrangement of the cells and cavities as that just described belongs to the majority of true cartilages, or to any of the fibro-cartilages.

Near the surface the articular cartilages are more laminated, and may be separated into thin lamellæ.

In the smaller articular cartilages the number of cavities and cells is more considerable, and the superficial layer of cells is not so well marked: the periphral cells are small indeed, but for the most part rounded; a few are found in the neighbourhood of the bone of an elliptical figure, but the middle layer presents circular cavities, with cells which are either single or multiple.

Nuclei. The nuclei contained in cartilage cells are mostly granular, but sometimes present a smooth aspect, and then are scarcely to be discriminated from particles of oil or fat: in form they are sometimes rounded, but in general they are irregular in shape, and follow more or less closely the contour of the cells in which they are enclosed; they also frequently enclose a nucleolus.

Usually but a single nucleus is contained in each cell; occasionally, however, two, three, and even several are included within it; and sometimes it happens that one or more of these is invested by a distinct cell membrane. (See Plate XXXI.)

The cells also include, as already remarked, particles of oil of a globular form and of a shining aspect: it has been suggested that these may probably in some cases be transformed nuclei.

The distinction of cartilages into true and fibro-cartilages, although useful for the purposes of classification, is to some extent artificial, since, on the one hand, some of the true cartilages, as old age approaches, become converted into fibro-cartilage, and on the other, the fibro-cartilages themselves, in the early period of their development, do not contain fibres, the cellular substance being hyaline, and identical with that of true cartilages.

The conversion of hyaline cartilage into fibro-cartilage has been observed to occur only in those cartilages which are subject to become ossified, as those of the ribs, the thyroid, &c.

Where ligaments are inserted into true cartilaginous tissue, this in the neighbourhood of such insertion always exhibits a fibrous structure, in consequence of the fibres of the ligament penetrating into the intercellular substance. These fibres are of a nature totally distinct from proper cartilage fibres, as will be seen hereafter.

FIBRO-CARTILAGES.

Fibro-cartilages differ chiefly from true or hyaline cartilages, in that the homogeneous intercellular substance is replaced in them by fibres endowed with elasticity; a transformation of structure of which we have seen that certain of the true cartilages are susceptible. (See Plate XXXI.)

The fibro-cartilages include those of the articulations which are united by synchondrosis, as the invertebral cartilages, and that of the symphysis pubis; the epiglottis and the cuneiform cartilages; the articulating cartilages of the glenoid cavity, and of the head of the superior maxillary bone; the inter-articular cartilage of the sterno-clavicular articulation; the cartilages of the ear, of the Eustachian tube, of Santorini, and those of Wrisberg.

There are, however, other differences besides the structural one alluded to: thus, fibro-cartilages are more opaque than the true, are of yellow colour more or less deep, and are endowed with a higher degree of elasticity and flexibility.

The fibres do not follow the same distribution in every fibro-cartilage: thus, in the tube of Eustachius, in the symphysis pubis, in the interarticular cartilage of the sterno-clavicular articulation, in those of the tempero-maxillary articulation they are placed nearly parallel to each other; in the intervertebral cartilages they ascend vertically from one osseous surface to the other; in the cartilages of the epiglottis and ear they are curved and interlacing.

In the outer part of each intervertebral cartilage the fibres form a distinct and compact stratum of a yellow colour, no cartilage cells in that situation intervening between them; the number of fibres, however, gradually diminishes towards the centre of the cartilage, which at the same time becomes less and less dense and firm, until at length in the very axis it is semifluid.

The cells of fibro-cartilages do not differ very materially in form and structure from those of true cartilages; they usually, however, contain more fat, are more readily separable from the fibrous base in which they are lodged, and more frequently encountered in the condition of parent cells.

The cells of the intervertebral cartilages and of the epiglottis present some interesting forms and modifications: thus, the cells which are situated in the harder parts of those cartilages are, on a vertical section, seen to be narrow and much elongated; while many of those imbedded in their soft and central parts are large and perfectly globular; many others of these, again, are in the condition of parent cells, and enclose either numerous nuclei or else many perfectly formed secondary cells; lastly, cells occasionally present themselves made up of concentric vesicles enclosed one within the other. Groups of adherent nuclei are also frequently met with deprived of an investing membrane. For representations of these several forms of cells, see the figures.

Henle* describes as occurring in the epiglottis certain large, spherical, or oval cells, presenting in their interior an oblong cavity from which proceed little branched tubes, which extend in all directions, even to the surface of the cells. These cells would appear to have some analogy with the osseous corpuscles. I have made diligent search for them in the epiglottis, but hitherto have failed to meet with them.

The fibro-cartilages are not soluble to the same extent in boiling water as the true, which are almost entirely so, and therefore yield less chondrine or jelly. The cells of these cartilages also resist the action of the water for a longer period than the intercellular substance.†

NUTRITION OF CARTILAGE.

Cartilages are amongst the number of non-vascular substances — that is, they do not, in general, receive into their own tissue distinct blood vessels, but derive their nourishment from those which are distributed to the parts adjacent to them.

Thus, the articular cartilages are supplied with nutriment from the vessels which are so freely distributed to the extremities of the bones: in young children and sometimes even in adults the synovial membrane which covers the free surfaces of the cartilages also carries vessels which assist in their nourishment.

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* Anat. Gen., vol. vii. p. 370.

† Meckauer (Cartilag. Structura, 1836,) appears to have been the first to give, under the direction of Purkinje, a complete and accurate description of the cartilages of the human body.

The independent or figured cartilages, as the ribs, &c., are surrounded by a membrane, composed of condensed cellular tissue, called the perichondrium: in this membrane the vessels which afford nutriment to the enclosed cartilages ramify. The ribs, moreover, contain grooves or canals, which, commencing on the inner edge of the rib, first run towards the centre, and then continue to pass forwards for some distance: these canals also contain blood vessels.

In the centre of ribs about to ossify a distinct medullary canal containing blood vessels in abundance is clearly perceptible.

Vessels are also contained in the fatty masses enclosed in some of the joints and called the glands of Havers; from these the adjacent cartilages doubtless imbibe a portion of nutrient plasma.

Amongst fibro-cartilages the synchondroses are stated to receive vessels. Nerves have not, as yet, been discovered in cartilages which may be irritated for any length of time without the slightest pain being occasioned.

During ossification, between the cartilage to be converted into bone and that which is to remain as the articular cartilage, a layer of vessels passes which, as the ossification advances, gradually retire and wholly disappear soon after birth.

As cartilages do not contain vessels, they are not subject to those disorders which depend upon errors of the circulation; that is, they are not liable to inflammation and its consequences. Ulceration of cartilages is indeed described by writers; but this term is wanting in accuracy when applied to the erosion of which cartilages are susceptible, and which is effected not through any operation occurring in the cartilage itself, but through the action of vessels which, proceeding from the synovial membrane, dip down into the cartilage, and occasion its partial absorption. For the same reason, cartilages do not readily become atrophied by pressure: thus, when an aneurism destroys the bodies of the vertebræ, the intervertebral cartilages are not at the same time removed, but resist for a long period the continued compression to which they are subject.

There is, however, one description of cartilage in which blood vessels regularly appear, viz., cartilages of ossification, in which may be included the costal and thyroid cartilages, their presence proceeding and accompanying the process of the formation of bone.

Cartilages, like all the extravascular tissues, imbibe fluid readily: thus, when immersed in a coloured solution, they assume the tint of the liquid in which they are placed. In jaundice, according to Bichat *, they present a greenish yellow tint, from the imbibition of a portion of the bile with which, in this disorder, the system is so pregnant.

GROWTH AND DEVELOPMENT OF CARTILAGES.

Cartilages, as already observed, consist of cells imbedded in a hyaline or fibrous base. In considering, then, the development of cartilages, the growth of both the cells and the intercellular substance must be discussed.

We will first describe the multiplication of cartilage cells.

The Cells. — Cartilage cells are multiplied in two ways.

1st. By the division of a single cell into two or more parts, each of which becomes, when the separation is completely effected, a distinct cell. The reality of this method of increase in the number of cells will become evident on the attentive examination of almost any thin section of cartilage, in the cells of which, but especially in those placed near the natural border, the several stages of their division may be clearly and satisfactorily recognised. (See Plate XXX.)

2nd. By the development of cytoblasts either in the intercellular substance, or else in parent cells. This mode of increase is a true reproduction, new cells being continually formed and developed. The first process of multiplication is of a nature totally distinct from reproduction, for although by it the cells are multiplied, no new ones are developed. There is the same differences between the two forms of cells, that having its origin in the division of a single cell, and that developed from a cytoblast, as there is between a slip and a seed. (See Plates XXX. and XXXI.)

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* Anat. Gen. t. iii. p. 192.

The parent or primary cells filled with the second or even the third generation of new cells, may be detected in abundance in almost any cartilage, but especially in the intervertebral cartilages. It is worthy of notice that the parent cells are usually situated near the centre of each cartilage, while the single cells, in which the process of division is best seen, are mostly found outside these. From this arrangement we may infer that the deeper seated cells are older than those of the circumference. Whether the latter are derived from the former, or whether they are formed on the external margin of the cartilage, it is not easy to decide; it is most probable, however, that from the circumstance that the parent cells are principally found in the centre of the thicker cartilages, and that it is in this situation that ossification commences, that the second proposition is the correct one.

It is a singular fact that the development of cartilage cells may be as readily followed out in old cartilages as in young, numbers of cells in process of division and in the stage of parent cells being readily distinguished in each. As after maturity cartilages do not undergo any increase in size and as from the preceding observations it would appear that new cells are continually being evolved, it must be presumed that the very old cells are absorbed and their place supplied by the younger ones.

In the multiplication of cartilage cells by division, a correspondence may be traced between cartilages and many of the lower tribes of animals and vegetables, especially with the majority of the algæ; and in the development of secondary cells in parent cells, they exhibit a still closer analogy with certain algæ of the genera *Hæmatococcus* and *Microcystis*, the cells of some of the species of which it would be impossible to distinguish from the isolated cartilage corpuscles of the epiglottis and intervertebral cartilages.

In these methods of multiplication, cartilage cells would appear almost to stand alone in the animal economy: thus it is certain that the red blood corpuscles, epithelial cells, and their various modifications into epidermis, nails, pigment cells, and hairs, are not multiplied either by division or by the development of secondary enclosed in primary or parent cells.

The analogy existing between the cells of cartilages and those of certain algæ has been noticed by Dr. Carpenter in the 3d edition of his "Principles of Human Physiology."

The Intercellular Substance. — Very young cartilages, and also the smaller ones of adults are constituted almost entirely of cells, with but little admixture of intercellular substance. As, however, these young cartilages grow in size, the relative amount of this substance increases, and the space between the cells becomes greater.

The augmentation of the intercellular substance takes place principally by a deposit of new layers on the exterior surface during the period of the development of cartilages; this mode of increase is proved by their separation after long continued maceration into distinct laminæ.

A second mode of increase of the intercellular substance has been stated to exist by Henle*, principally in the cartilages of ossification, and under no circumstances in the fibro-cartilages, viz., by the thickening of the walls of the cells which become confounded with or melted down into the intercellular substance, the cavity in which the cells are lodged being diminished, or this also augmenting at the same time. The proofs adduced in favour of this method of increase are not convincing.

It has already been stated that in the true cartilages which are subject to ossification fibres appear; these fibres as well as the analogous ones of fibro-cartilages, are probably of a nature wholly distinct from those of ordinary cellular tissue, and which have their origin in cells; under no circumstance can either cells or nuclei be discovered in the fibres of cartilages.

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* Anat. Gen., vol. vii. p. 376.

Cartilage is not capable of regeneration: when it has been fractured, the union of the surfaces is very incomplete, and principally by means of cellular tissue.

The formation of cartilage almost invariably precedes the development of bone, of which we shall shortly have to speak more particularly in the Chapter on Bone.

Masses of cartilage are also occasionally produced upon the external surface of the synovial membrane of joints; these are at first peduncated, but at length cease to have any connexion with the organization, and move freely about in the cavity of the joints.

Occasionally, though rarely, cartilage is developed in the cellular tissue of glands, forming a solid tumour, which was first described by Müller under the name of *Enchondroma,* and of which I recently had the pleasure of receiving a very excellent example from Dr. Letheby.

USES OF CARTILAGES.

The uses of cartilages are of a mechanical nature, depending upon certain physical properties.

Thus we find them to be situated in localities, where solidity is required in combination with flexibility and elasticity.

In the larynx, the flexibility and elasticity of cartilages assists in the modulation of the voice.

In the nose, so liable to injury, their flexibility often allows this organ to sustain severe blows without detriment.

The articular cartilages protect the bones from injury to which they would be otherwise so subject in the sudden and violent exertions of the body, as in jumping on account of their solid and unyielding nature.

The intervertebral cartilages are exceedingly elastic and flexible, and permit the free movement of the spinal column in almost any direction, and which is so necessary in the execution of the various motions of the body.

The articulations united by synchondrosis, as that of the pubis, are remarkable for their strength, although at the same time it admits a slight degree of extension and compression.

Lastly, the epiglottis is enabled to preserve the erect position so essential to the maintenance of life in consequence of its exceeding elasticity.

Art. XV. BONE.

The next tissue to be considered is the osseous.

Bones are divided after their form into long, flat, and irregular: long bones consist of a body or shaft termed *diaphysis*, hollowed out in the centre into the medullary canal, and of two extremities called *Epiphyses*, and which in early life are distinct from the shaft; each long bone, moreover, is made up of two modifications of bony structure, the cancellous and the tabular; the former is loose and reticular, the latter hard and compact: of the one, the great bulk of the epiphyses are constituted; of the other, the diaphysis is chiefly formed: in flat and irregular bones, the medullary canal is wanting; the first consist of an inner and outer table of compact bony tissue, enclosing a thin plate of cancellous structure, termed *Diploœ*, and the latter are composed principally of cancelli, enclosed in thin and irregular osseous laminæ.

STRUCTURE OF BONES.

The two elements into which all bones resolve themselves are osseous corpuscles and laminæ; the latter, according to the plan of their arrangement and development, give rise to the cancelli, medullary canals, and plates of which bones are constituted.

Cancellous Structure.

The cancellous structure of bone is made up of thin and inosculating plates of bony matter, which enclose spaces between them, and all of which freely communicate with each other: these spaces are called *medullary cells.* Each plate is also compounded of several laminæ, in the intervals between which a few bone corpuscles exist.

The fact of the free communication of the medullary cells is proved by the two following experiments: —

Thus, when mercury is poured into a hole made in the extremity of a long bone, or on the surface of a flat or short one, it will traverse all the medullary cells, and escape by the apertures which exist naturally on the exterior of bones.

Again, if a bone be cut through at one of its extremities, the natural openings on its surface being at the same time closed, and if then the bone be exposed to the action of heat, all the marrow will escape slowly by the cut extremity. *

The spaces described by the medullary cells are irregular in size and form, those which are first developed being smaller than those of older formation (see Plate XXXIV. *fig.* 3, 4.): they are usually of an elongated shape, their long axes being parallel to that of the bone itself: when viewed transversely, they are seen to be more or less rounded, but irregular in outline: it is in the transverse sections that the bone cells and lamellæ are best seen.

Medullary cells in the recent state are filled with fat vesicles, with blood-vessels, and with granular nucleated cells analogous to those of epithelium: these last occur in considerable quantities in the cancelli, and especially in those of fœtal bones, in which the fat vesicles are for the most part absent. (See Plate XXX. *fig.* 4.)

They inosculate freely with the medullary canals situated in the outer and compact plates of bone.

Canalicular Structure.

The compact tissue of bones is traversed by canals, which have been termed medullary from the fact of their being in communication in the long bones with the great central medullary cavity, and from the circumstance of their being partly occupied with medullary matter. They are also called Haversian, after their discoverer.

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* Bichat, Anatomie Générale, t. 111. p. 25.

These canals are situated between the laminæ of which bone is composed, and take a course in the long bones, in which they are best seen, parallel to their axes, being also joined together by short transverse branches: they thus form a network of tubes analogous to that exhibited by the minute vessels which they convey and protect; the form and sizes of the meshes vary: in the long bones they are elongated. (See Plate XXXII. *fig.* 4.)

They communicate, in the long bones, with the medullary cavity, dilating into cells or vesicles, from which a short tube proceeds previous to their entrance into it; they also open upon the external surface of all bones by somewhat expanded apertures, and inosculate freely with the medullary cells.

Medullary canals are not all of equal diameter throughout the compact tissue of a bone; those situated between the external plates are two or three times smaller than those which are placed more internally. (See Plate XXXII. *fig.* 1.)

In a transverse section the canals are seen to be either circular, oval, or rarely angular.

In the flat bones the course of the medullary canals is more irregular than in the long bones; in the parietal bones they proceed diverging from the parietal protuberance towards the margins of the bone; and in the frontal from the supra orbitar ridge towards the coronal suture.

In the long bones, near their extremities and in the vicinity of the articular cartilage, these canals end in blind or cæcal extremities, a single canal passing up into each of the prominences, into a number of which the articular surface of bone is elevated.

It is these canals which impart the striated structure presented by bone, and which is visible to the unassisted eye; in longitudinal sections they are frequently cut through, and their cavities exposed.

The contents of medullary canals are similar to those of the medullary cells, of which they are to be regarded as a modification, there being an insensible transition from the one to the other.

Drs. Todd and Bowman recognise two forms of Haversian canals, one of which carries veins, the other arteries, a single vessel being distributed to each; those canals which contain the veins are stated to be larger than those which convey the arteries, and to be dilated into a pouch or sinus at the situation where two or more canals unite to form a single larger tube.

Lamellæ.

The more essential constituents of true and fully developed bone are, as already observed, lamellæ and bone cells; the medullary cells and canals just described are merely definite spaces existing between the lamellæ, the arrangement and ultimate structure of which we shall in the next place proceed to notice.

It is principally by the successive development of new lamellæ that bones increase in diameter; these are usually deposited in the direction of the axis of the bone; if, therefore, a transverse section of a long bone be made and examined with the microscope, the lamellæ will be seen to be arranged as follows: first, several layers will be observed to pass entirely round the bone, secondly, others will be noticed encircling each Haversian canal, and lastly, irregular and incomplete lamellæ occupy the angular spaces intervening between the sets of lamellæ concentrically disposed around each canal. (See Plate XXXII. *figs.* 1, 2, 3.)

The number of layers which pass interruptedly around the bone are not very numerous, being generally less than twelve; the amount of those which encircle each Haversian canal varies from two or three to upwards of twelve, the smallest number of lamellæ usually appertaining to the smallest canal. (See Plate XXXII. *fig.* 1.)

Examined with an object-glass of the fourth of an inch focus the lamella, after the separation of its earthy matter by means of dilute hydrochloric acid, exhibits a delicate structure, the precise nature of which it is not easy to determine; its surface will be seen to be marked out into innumerable lozenge-shaped spaces, one side of each of which is concealed by a dark shadow, and the divisions between which are without shadow. (See Plate XXXIII. *fig.* 4.)

This interesting structure was first distinctly pointed out by Dr. Sharpey[*], who conceives that it arises from the crossing and union of fibres; these, however, cannot be traced out and displayed as separate fibres, owing, it is presumed, to their being united or fused together at the points where they cross each other; it sometimes happens, however, that at the torn edge of a lamella a short projecting process may be seen which presents much the aspect of a true fibre.[†]

The appearance presented by a lamella thus figured might be compared to the engine-turned case of a watch, and it might also be conceived that it was produced by the union of a number of diamond-shaped cells, and not by the crossing of fibres.

One argument in favour of the fibrous constitution of the lamellæ may be derived from the fact that the cancelli of bone in process of development clearly exhibit a fibrous structure.

Cross sections of the lamellæ may also sometimes be observed to be marked with short and radiating lines, which most probably depend upon the structure already noticed.

The osseous lamellæ are likewise perforated necessarily with numerous minute apertures occasioned by the canaliculi of the bone cells, and which when seen with a low power appear like so many small dots; they contain also, scattered throughout their substance, multitudes of granules of earthy matter.

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[*] Quain's Anatomy, 5th edition, part ii. p. cxlii.

[†] It would appear to be probable from the following quotation that Henle had seen the structure above described. "The lamellæ examined on their flat side have appeared to me to be generally hyaline or finely dotted, but sometimes also fibrous; the fibres are either pale and as though composed of grains, or obscure and rugged; one never succeeds in isolating them for a certain space, because they are branched, interwoven, and in a word perfectly identical with the fibres of fibro-cartilages."

The only really necessary constituents of bone would appear to be the cellular tissue and earthy matter. The combination of these two forms bone in its simplest condition. The medullary cells, Haversian canals, and bone cells, are connected only with the growth and nutrition of bone and occur seldom, except where the size of the bony formation renders their presence necessary for its growth and support.

Bone Cells.

Distributed throughout the cancellous and the compact portions of bone, cells of a peculiar structure occur in considerable quantities.

Concerning the nature of these cells much difference of opinion prevails; by some they are described as mere vacuities existing in the tissue of the bone, by others as hollow cells, as nuclei of cells, and as true nucleated corpuscles. That the bone cells take their origin in nucleated cells cannot be doubted.

The circumstances which have given rise to the notion of their being mere vacancies or lacunæ are the passage of fluids through them, their infiltration with solid matter, and the optical appearances sometimes presented by them. All these circumstances admit, however, of explanation on the supposition of their corpuscular origin.

That they are derived from granular cells may be proved, it seems to me, by the study of the development of bone, they being in growing bones first traceable as nucleated corpuscles, a condition to which they may be again reduced in an adult bone by the removal of the earthy matter. This appearance is best seen in the large bone cells of the Siren, Proteus, or Menobranchus.

The bone cells, which are very numerous, are situated between the osseous laminæ already described, and by which they are compressed; they thus present in all sections of bone an elongated or flattened form, and in transverse cuttings those facing the Haversian canals appear not merely elongated, but also slightly curved, the concavity of the arc being directed inwards towards the canals, and the convexity outwards in the contrary direction. (See Plate XXXII. *figs.* 1, 2.)

When viewed as transparent objects they appear black, and when as opaque they are of a pearly whiteness.

From the margins of each bone cell proceed a number of branched canals, which, passing through the lamellæ situated on either side of the cell, inosculate freely with the canaliculi given off by the bone cells of the contiguous lamellæ (see Plate XXXII. *fig.* 3.); this process of inosculation being frequently repeated between the cells of each lamella, a communication is thus established between the medullary cavity on which the canaliculi of the first series of cells opens, the Haversian canals, and the external surface of the bone. The reality of this communication may be attested by applying a drop of oil of turpentine to a section of dry bone placed beneath the microscope, when the passage of the fluid through the bone cells may be followed with the eye. This experiment was first suggested by Drs. Todd and Bowman.

The canaliculi of bone cells treated with acid usually disappear, the body of the cell alone remaining.

The size of the bone cell throughout the whole of osseous vertebrate series, stands in relation to that of the red blood disc; and Mr. Quekett, who has instituted an inquiry into their form and size in a great variety of animals, has arrived at the conclusion that the class to which any animal belongs, whether that of Beasts, Birds, Reptiles, or Fishes, may be determined by the two particulars referred to. This discovery is likely to be especially useful in the determination of the true position in the animal series of many fossil bones, which but for it would have continued to be enveloped in uncertainty and conjecture.

In many osseous fishes the bone cells appear to be wanting, they having merged into canaliculi, which are often of considerable size.

Marrow of Bones.

The medullary cavity of adult long bones, the medullary cells, and the larger medullary canals, all contain a loose cellular tissue, in the meshes of which a greater or less amount of marrow or fat cells is enclosed. (See Plate XXX. *figs.* 3, 4.)

In fœtal and very young bones the fat vesicles are wanting in the three situations named, the place of fat being supplied by immense numbers of the small granular nucleated cells, which have already been referred to. (See Plate XXXIII. *fig.* 5.)

It has been stated that the medullary cavity, cells, and canals all communicate freely; the marrow therefore and its enclosing cellular tissue are everywhere continuous.

Periosteum.

The external surface of all bones, with the exception of their articular extremities, is covered with a dense membrane composed of fibrous tissue, which is very rich in blood-vessels, and which is called the periosteum.

The internal surface of the medullary cavity, cells, and larger Haversian canals, is also lined by a vascular membrane much more delicate in structure, which may be regarded as an internal periosteum.

It is by means of the vessels which ramify through these membranes that the nourishment of the bone is secured.

Vessels of Bone.

Bones are richly supplied with blood-vessels, which penetrate every part of their structure.

Thus externally, branches, principally arterial, proceed from the periosteum, enter the numerous apertures of the Haversian canals, and ramifying through these form a capillary network; these external periosteal vessels may be seen with the unaided eye extending into the bone like so many fine threads on the cautious detachment of the periosteum.

Again, in the long bones, a large artery penetrates by an oblique canal situated at the junction of their upper and middle thirds, into the medullary cavity, and sends branches upwards and downwards, which ramify on the membrane of the medulla or internal periosteum, some of these proceed onwards into the medullary cells, and others inosculate with the capillaries of the Haversian canals already referred to.

The flat and irregular bones are furnished not with a single vessel of large calibre, but with several of smaller size.

These larger arteries are accompanied by veins, whereby a portion of the venous blood is returned from the bone.

Breschet*, moreover, has described in the flat bones, and especially in those of the cranium, a system of osseous canals, which contain only veins, and which are furnished with valves, which is not the case with the other veins of bones.

The walls of these canals, which ramify after the manner of vessels, are pierced with apertures, by which they receive small capillaries: they traverse principally the spongy portion of bones, afterwards they pass through the compact part, and finally terminate on the external surface of the bone.

These canals are best seen in the flat bones of the cranium, which should be dried, and the outer table of compact substance removed.

Lymphatics have been observed in some few instances in bone.

Nerves of Bone.

Nerves have not hitherto been satisfactorily traced into bones; nevertheless, the great pain experienced in diseased conditions of them proves incontestably the existence of nervous fibrillæ.

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* N. A. N. C. xxiii. P. i. p. 361.; Recherches Anat. Physiolog. et Pat. sur le Système Veineux, Paris, 1829. fol.

GROWTH AND DEVELOPMENT OF BONE.

Growth of Bone.—The situations in which the chief increase of bone occurs are commonly stated to have been accurately determined by means of the different madder experiments instituted by numerous observers.

If an animal be fed for a short time with the root of madder, its bones will become tinged with the colouring matter of that plant, between which and the phosphate of lime of the bone a great affinity exists.

On a close examination of sections of a growing long bone it will be observed, however, that the tissue of the bone is not uniformly coloured, but that in a transverse cutting the colour is principally situated in the outer part. The same fact is shown also in longitudinal sections, which, however, if they embrace the entire length of the bone, will also be observed to be tinged with the colouring matter towards either extremity.

Again, if a magnifying glass be applied to a thin transverse section of the growing bone of an animal fed upon madder, each Haversian canal will be seen to be surrounded by its ring of colour. For this beautiful illustration of the effects of madder we are indebted to Mr. Tomes. (Plate XXXIII. *fig.* 6.)

These several observations have been presumed to prove that bones increase *in length* principally by additions of new matter to their extremities, and *in breadth* by the deposition of new laminæ of bone on their outer surface, as well as by the formation of fresh lamellæ in each Haversian canal, which last grow and expand in size simultaneously with the laminæ placed external to them after their first formation.

Now, although it is very probable that bones increase in diameter to a great extent by the addition of new matter on the external surface, and although it is quite certain that they become elongated by the formation of bony matter at their extremities, it appears to be most clear that we are not justified in coming to any such conclusion from the results of the experiments with madder. All that these celebrated experiments really seem to prove is, that bones in contact with blood-vessels containing the colouring matter of madder readily imbibe and retain that principle in common with the liquor sanguinis.

The bones of old animals are coloured with much more difficulty than those of young; a few hours in very young animals being sufficient to ensure their colouration.

Development of Bone. — We come now to consider the exact process of the development of bone.

Bone is developed either in membrane or in cartilage; when in the former it may be termed intra-membranous, and when in the latter intra-cartilaginous ossification.

Intra-membranous Form of Ossification. — We will consider, first, the intra-membranous form of ossification. Dr. Nesbitt * was the first to distinguish between the two types of ossification. More recently Dr. Sharpey † has described clearly and satisfactorily the steps of the intra-membranous development. This form he considers to belong to certain flat bones of the cranium, as the parietal and portions of the frontal and occipital bones, as well as to the outer surfaces of the long bones.

The first perceptible ossification of the parietal bone, which may be selected as one of the best examples of this form of osseous development, consists of a network of spiculæ of bone, the outermost of which radiate in lines towards the circumference, and are connected by short transverse branches. (See Plate XXXIII. *figs.* 1, 2.)

As the ossification proceeds, the first-formed spiculæ, in the centre of the bone, become greatly increased in thickness, and the spaces between them much diminished in size; the ossification continues thus to spread and consolidate until the parietal meets the neighbouring bone, with which it is at length united by suture.

If, however, the microscope be brought to bear upon one of the newly-formed spiculæ before the entire bone has attained any considerable development, it will be seen that the ossific deposit takes place in the fibres of fibro-cellular tissue, intermingled with which numerous granular and nucleated cells occur; these fibres, which are disposed in bundles, invariably precede the deposition of bony matter, and mark out the course of the future spiculæ. (See Plate XXXIII. *fig.* 3.)

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* Human Osteogony, Lond. 1736.

† Dr. Quain's Anatomy, edited by Mr. Quain and Dr. Sharpey, 5th edition.

The granular cells just noticed have been observed by Dr. Sharpey, who remarks upon their distribution in the direction of the future spiculæ, and who considers that they are connected in some way or other with the process of ossification.

There can scarcely be a question but that they are the bone cells in a rudimentary state, their conversion into which it is not difficult to trace.

Now it does not appear that cartilage is at all concerned in any one stage of the development of the parietal bone of the human embryo. In that of the sheep and some other animals a lamina of cartilage is present in connection with the parietal bone; but this takes no part in the process of ossification, but merely serves as a support to the newly-developed bone, and extends beneath the first-formed portion of it alone.

As the ossification advances still further, the interstices between the first-formed spiculæ become filled up, grooves appear on the surface of the bone; these radiate from the centre towards the circumference, and ultimately become converted into canals, which, being lined with a number of concentric laminæ, at length constitute complete Haversian canals. The bone is then completely formed.

Intra-cartilaginous Ossification. — It has until recently been supposed that the formation of bone always takes place in cartilage; this notion, as we have seen, is erroneous.

Ossification is also usually described as the *conversion* of cartilage into bone; this idea will be presently shown to be equally erroneous, and the fact demonstrated that the intra-cartilaginous ossification does not differ essentially from the intra-membranous form.

If the microscope be brought to bear upon a thin longitudinal section of an ossifying fœtal bone, in connexion with its cartilaginous epiphysis, the following particulars will be noticed.

First, it will be observed that the cartilage cells in the neighbourhood of the bone, instead of being scattered irregularly throughout the intercellular substance, are arranged in several consecutive and alternating rows or files, the lowermost of which dip into and are surrounded by osseous cups and septa; that the cells forming the lower portion of the lowest tier are larger, and less compressed, than those which enter into the formation of the upper part of each lower series, and that they are separated from each other by distinct portions of intercellular substance. Secondly, it will be remarked that the extremities of the still soft bony spiculæ invade and extend into the spaces which intervene not merely between the rows of cells, but also between the individual cells, and further that granular and probably cytoblastemic particles are deposited in this intercellular substance, particularly where this comes into contact with the cartilage cells themselves. (See Plate XXXIV. *figs.* 1. 4.)

As the process of ossification advances, the cell wall of the cartilage cells becomes absorbed; granular corpuscles are next generated in the primary cancellus, after which the nuclei of the cartilage cells (which are observed to become smaller the deeper they lie in the bone), are removed by absorption; finally, the small septa intervening between the individual cartilage cells are removed, the larger medullary spaces being thus formed. (See Plate XXXIV. *fig.* 4.)

Furthermore, in these precursory and even in the older spiculæ, fibres analogous to those in which the spiculæ of the parietal bones are developed may be abundantly detected.

Such is a brief sketch of the several steps of the intracartilaginous form of ossification.

Now the process which we have just described is constantly in progress; cartilage cells on the one side are continually being developed in the epiphysis; they are also constantly marshalling themselves into rows or columns, the lowermost cells of which dip into the cancelli and become absorbed; on the other side the cancelli of the bone are continually invading the intercellular spaces of the cartilage.

It is thus that a bone grows in length. Each epiphysis of a long bone, however, after a time becomes a centre of ossification; this proceeds to meet that of the shaft; a layer of cartilage usually, however, intervenes between the two, until the period of the full development of the osseous system, when this layer becomes absorbed, and the shaft and the epiphysis become consolidated by bony union. The first trace of ossification of the epiphysis in the human subject is usually apparent at about the ninth month.

We have now to ask ourselves the question, how does the bone increase in diameter? We have shown that it is generally considered as proved by the madder experiments already referred to, that a long bone increases in breadth by the deposition of new lamellæ at the circumference, as well as in the cavities of the medullary cells and Haversian canals; but we have seen also from what has been already said in reference to the different sizes of the external and internal Haversian canals and their mode of formation, that each of these canals is continually undergoing a process of expansion, and it is by this expansion that the chief increase of the diameter of a bone takes place. It was formerly supposed that a layer of cartilage existed in all growing bones on their external surfaces, but we now know that such is not the case, and that the new osseous deposit takes place in fibres. If it were necessary that a layer of cartilage should exist in the situation named, it would be equally requisite that it should be present in each medullary cell and in each Haversian canal.

The small granular corpuscles already referred to as occurring in the cancelli of all bones, but especially in those of the fœtus, it would thus appear are developed in considerable quantities at a very early period of the development of bone; they are generally apparent in the third or fourth tier of the first formed and small cancelli, and while the nuclei of the cartilage cells yet exist. (See Plate XXXV. *fig*. 3.)

It will now be perceived that the intra-cartilaginous form of ossification is identical with the intra-membranous type in all essential particulars.

It will also readily be seen, that this view of the process of ossification differs very considerably from the more recently expressed opinions on the subject; those, for example, of Drs. Todd and Bowman, and of Mr. Tomes.

The authors of the "Physiological Anatomy" consider that the nuclei of the cartilage cells become developed ultimately into the bone cells.

There are many considerations which would lead to the conclusion that such a transformation is but little probable, the following of which may be referred to: —

The formation of bone independent of cartilage, as in the intra-membranous type of ossification.

The small number of the cartilage cells compared with the vast quantities of bone cells which exist in even a young bone.

The impossibility of explaining why the permanent cartilages should not, like the temporary, be constantly subject to ossification, since they are both organised in precisely the same manner.

The proof that cartilage cells have no further stage of development to pass through, manifested by the fact of the occurrence of parent cells in all cartilages, whether temporary or permanent.

The chief new points contained in Mr. Tomes's views * are the ossification of the walls of the several cartilage cells which form each roll or column, and the conversion of a number of these, by the absorption of the contiguous walls of the cells, into a single cavity or tube, which becomes filled with a granular blastema; this tube Mr. T. considers to be an

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* See Art. Osseous Tissue, Cyclop. of Anatomy and Physiology.

Haversian canal, and its wall to constitute ultimately the outer lamina of such canal.

The arguments adduced in disproof of the opinion that the nuclei of the cartilage cells become converted into bone corpuscles, apply with equal force against the idea of the calcification of the walls of the cartilage cells.

Bone Cells. — Bone cells, then, according to the views of the author, are not transformed nuclei of cartilage corpuscles, but take their origin in distinct granular cells, which may be clearly seen in the growing spiculæ of bone dispersed amongst the fibres in which the earthy matter of bone is first deposited, and which at length become entirely imbedded in the earthy deposition.

As, however, it is most probable that a development of bone cells and new laminæ of bone are ever in progress even in adult bones, we should expect to encounter in the cancelli of bones of every age fibres of cellular tissue and granular cells; both these do occur in them, and especially the latter, which are met with in great numbers.

These granular nucleated cells are more numerous in fœtal and young bones than in those of older formation; in the former, indeed, they almost entirely fill up the cavities of the cancelli: in the latter, although they are still numerous, their place is supplied with fat vesicles, which are not present in the former.

It seems to me to be not improbable that two kinds of granular cells may exist in the medullary spaces, &c., one consisting of rudimentary bone cells, and the other connected with the elaboration of the marrow, which occupies the medullary cavity, medullary cells, and larger Haversian canals.

It might be supposed that these granular cells were the white corpuscles of the blood escaped from the ruptured vessels, the red blood discs having been absorbed; this notion is, however, disproved by the fact that many of them are much larger than the colourless corpuscles of the blood. (See Plate XXXIII. *fig.* 5.)

The existence of a granular blastema in the cancelli, &c.

of bones was first observed by Drs. Todd and Bowman[*], who considered that it was concerned in the development of blood-vessels.

Presuming it to be proved that the bone cells are derived from true corpuscles, we have yet to decide whether we are to believe with Schwann[†], that they are complete cells, and that the canaliculi are prolongations of the walls of these cells; that, in fact, they possess a structure conformable with that of the stellate pigment cells of the skin of the frog, or of the *lamina fusca* of the eye; whether we are to consider with Gerber[‡], Bruns[§], and E. H. Mayer[‖], that they are the nuclei of primitive elementary cells and that the canaliculi are prolongations of these; whether, again, we are to regard them with Henle[¶] as the cavities of cells, the walls of which have become thickened, and the canaliculi of which proceed from the central cavity through the thickened walls of the cells, as do the porous canals of many vegetable cells; lastly, whether we are to believe, with Todd and Bowman, that the canaliculi proceed from the nucleus, which afterwards becomes absorbed, and that thus the lacuna is left.

That the first view is the correct one, and that the bone cells are to be regarded as complete corpuscles, the canaliculi of which are formed by the extension of the cell wall, is, I think, proved by watching the formation and development of bone cells in growing spiculæ and by the action of dilute hydrochloric acid, which, by removing the earthy matter, allows the granular texture, which originally characterised them, to be again seen.

The last points left for consideration in reference to the development of bone are, the modes of formation of the medullary cavity, medullary cells, and Haversian canals.

Formation of medullary Cavity. — Traversing the substance of each cartilaginous epiphysis, a number of large and branched canals may be seen in both transverse and longitudinal sections. (See Plate XXXV. *figs.* 1, 2.)

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[*] Physiological Anatomy, Chap. 5.

[†] Mikroskopische Untersuchungen, pp. 35. 115.

[‡] Allgemeine Anatomie, p. 104.

[§] Ibid. pp. 240. 252.

[‖] Muller, Archiv. 1841, p. 210.

[¶] Anat. Gen. t. vii. p. 409.

The majority of these proceed directly from the ossified part of the shaft in connection with the epiphysis; in this situation they are of larger size, and are also fewer in number, than they are higher up in the epiphysis, not exceeding usually five or six, but becoming multiplied, by the giving off of branches, to as many as fourteen or sixteen; others, however, enter the epiphysis from the sides, near the junction of the bone and cartilage.

The interior of these canals is occupied with blood-vessels and with granular nucleated cells, precisely like those existing in the medullary cells of bone. (See Plate XXXV. *fig.* 3.)

The cartilage cells in a transverse section of the canals immediately surrounding their orifices are disposed in a rayed manner.

Having thus described the structure, contents, and distribution of these canals, we will next inquire their use. (See Plate XXXV. *fig.* 3.)

If a number of transverse sections be made not merely of the cartilaginous epiphysis, but also of the bone in connection with it, and if these be examined in the order of their removal, it will be observed, first, that in those sections which are made from the cartilaginous epiphysis most removed from the bone, the apertures of these canals are small and numerous (see Plate XXXV. *fig.* 1); second, that in the sections taken from the proximal end of the epiphysis the canals are fewer in number and their orifices larger (see Plate XXXV.); thirdly, that in other slices, which include a portiorn of both catilage and bone, the latter always commences on the circumference of the section, proceeding gradually inwards, the portion of cartilage surrounding the canals in question being the last to become ossified (see Plate, XXXV. *figs.* 2, 3.); fourthly, in cuttings made below the cartilage and through the bone, spaces four or five in number, filled with granular cells corresponding in situation with the afore-described canals, will be observed; fifthly, in others carried still deeper into the bone, these several apertures will have coalesced into one large space — the rudimentary medullary cavity.

From these several particulars, I therefore infer that the canals in question are intimately connected with the formation of the medullary cavity; and that the absorption of the cancelli situated between each of them is brought about by the vessels contained within them, aided also probably by the granular cells.

Were the canals merely destined to convey to the cartilage the nourishment necessary for its transformation into bone, it might be expected that they would serve as so many centres from which the ossification would proceed; we have seen, however, that the cartilage in their immediate vicinity is the last to be removed, and its place supplied by bony cancelli.

Medullary cells. — The primary cancelli are small, studded with granules, form closed cavities, and do not contain bone cells. (See Plate XXXIV. *figs.* 2, 3.) The secondary and larger cancelli are formed by the absorption of the numerous septa of the primary cancelli; they do not form closed cavities, but communicate freely together and contain bone cells imbedded in their parietes. (See Plate XXXIV. *fig.* 4.)

Haversian canals.— The Haversian canals are generally described as being formed by the filling up of certain of the medullary cells, in consequence of the successive deposition of new laminæ of bony matter. It seems to me, however, to be very questionable, whether they are ever formed in the manner indicated, and if so, such is assuredly not the general mode of their formation.

I am induced to take a different view of their formation, and consider they originate as follows: —

The surface of all bones, whether long, flat, or irregular, is observed to be marked with numerous grooves of different sizes and depths. In the recent state these are occupied with blood-vessels, and it is around them that successive layers of bone are deposited, until at length the vessels become entirely included and a perfect canal is formed.

In transverse sections of long bones, grooves and partially developed canals may generally be seen along the outer margin of the cutting.

This view of the formation of the Haversian canals also accords well with other characters presented by transverse sections of bone. Thus, in all such, it will be seen that the smallest Haversian canals are situated in the external part, while the larger canals are placed internal to these: it will also be observed, that the smaller canals are surrounded by the fewest number of concentric lamellæ, and the larger by the greatest number. (See Plate XXXII. *fig.* 1.) Now the fact of an additional number of lamellæ encircling the larger canals proves two things: first, that these large Haversian channels are of older formation than the small; and second, that each lamella grows or expands after its deposition, whereby the calibre of such canals becomes increased, which is contrary to the generally entertained notion of the formation of the Haversian canals, *viz.* by the filling up of the large cancelli, brought about by the continual deposition of new osseous lamellæ, the outermost of which, for such a result to ensue, must remain stationary in point of size.

ACCIDENTAL OSSIFICATION.

The abnormal growth and development of bone is a very common pathological occurrence. Thus we have it occurring on the surface of the bones themselves in the form of exostoses, in the permanent cartilages, in the cellular tissue of muscles, glands, the ovaries, membranes, as the coats of the arteries, and probably occasionally also in that of every other tissue and organ of the body.

It is not, however, every ossific deposit which presents all the characters of bone: thus those contained in the ovaries, in the mesenteric glands, and in the coats of the arteries, usually want the more conspicuous elements of bone, the bone cells and lamellæ, although these have been met with in ossific depositions remote from all connexion with bone.

In the reparation of fractures we have a development of true bone preceded by the formation of cartilage.

ART. 16. THE TEETH.

THE tissue of the teeth is to be regarded rather as a modification of the osseous than as a distinct type of structure: the truth of this remark is especially apparent on an examination of two of the three substances which enter into the formation of each tooth, *viz.* the cementum and dentine; the third constituent, the enamel, is more nearly related in its organisation to the epithelium, of which indeed it is a condition.

Each tooth consists of two parts: the body or crown, and the root or fang; the limits of these are indicated by a slight contraction called the neck; the crown is either simple or divided, and the same is the case with root also: those teeth which have a simple crown are called incisors and canines, those with a double crown bicuspids, and those with the crown quadruply divided molars. Again, the substance of each tooth is divisible into three portions, each of which presents characteristic differences; these have received the names of *dentine*, *cementum*, and *enamel.*

The dentine, also called the ivory, forms the chief bulk of the tooth, occupies a central position, and its interior contains the pulp cavity.

The enamel forms a layer of compact substance which immediately surrounds that portion of the dentine of which the crown of the tooth is made up.

The cementum, also called *crusta petrosa,* has a distribution the very reverse of the enamel, and extends principally around the fangs of the teeth, and terminates at the neck of the tooth, in fact, just where the enamel commences.

STRUCTURE OF THE TEETH.

Having thus sketched the general position of the three constituents of the teeth, the consideration of the intimate structure of each may next be entered upon.

Dentine. — The dentine is constituted of numerous tubes imbedded in an intertubular substance; these tubes commence at the pulp cavity, on the surface of which they open, and from which they proceed in a radiate manner, terminating on the borders of the dentine; those arising from the upper part of this cavity ascend almost vertically, those from the sides more obliquely, and those from the lower portion pass either horizontally outwards, or else descend somewhat.

These tubes diminish in size from their commencement to their termination: they are branched; at first they divide in a dichotomous manner; their subsequent ramifications are numerous, minute and arborescent, and they inosculate freely with the similar branches proceeding from the adjacent tubes: those tubes which proceed towards the cementum are remarkable for the very great number of branches into which they divide.

The tubes of the dentine in their passage outwards do not run in straight lines, but describe in their transit two or three large curves, and each of these primary curves, when examined with a higher power of the microscope, will be observed to be made up of numerous smaller and secondary curves; both the large and small curvatures of one tube correspond with those of another.

Such is the usual course and distribution of the tubes of the dentine: several modifications of them, however, still remain to be noticed.

Thus sometimes a tube in its passage will dilate into a bone cell, and again proceed onwards to its destination as a tube; at others a number of them, even in the centre of the dentine, will break up and form a cluster of bone cells; again at others the tubes frequently become transformed into or terminate on the margin of the dentine in bone cells. This gradual transformation of the dentinal tubes into bone corpuscles, and their termination in the same, is especially seen in that portion of the dentine contiguous to the cementum.

The usual method of termination of the dentinal tubes is in fine and inosculating branches on the surface of the dentine. Sometimes, however, the tubes anastomose in a peculiar manner and form distinct loops, at others the terminal branches pass out of the dentinal substance, and extend either into the cementum or the enamel; this extension into the former is a very frequent occurrence.

For illustrations of these several modifications, the majority of which have been pointed out by Mr. Tomes in his excellent lectures*, see the figures.

The surface of the dentine presents many elevations and depressions: to these the enamel is accurately adapted; it also exhibits the hexagonal impressions of the enamel fibres.

The substance of the dentine is seen also occasionally to be traversed with canals for blood-vessels, analogous to the Haversian canals of bone.

The pulp cavity of the teeth of old persons frequently becomes filled up, and even obliterated, by a secondary formation of dentinal substance, and which may be called the secondary dentine. This dentine results from the ossification of the pulp by the vessels of which it is traversed, and from the margins of the canals containing which the dentinal tubes proceed in a radiate manner. (See the figures.)

Mr. Nasmyth regarded this secondary dentinal formation as distinct from the other structures of the tooth, and called it the fourth dentinal constituent.

The dentinal tubes form but one element of the dentine; the other is the intertubular substance.

This is described by Mr. Nasmyth as constituted of elongated cells, in the form of bricks placed end to end, and a tier of which exists between every two tubes: Henle, on the other hand, declares it to be fibrous. It would appear not to present any regular tissue, but to be simply granular.

Occasionally, I have encountered in it globules of various sizes refracting the light strongly, and presenting the appearances of oil or fat vesicles. It has occurred to me that these might be fat cells which had become included in consequence of the ossification of the pulp, and which always contains a greater or less quantity of fat cells. (See figure.)

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* See Lectures in Medical Gazette.

Some sections of dentine which I have examined have exhibited numerous reticulated markings, the results of fracture of the intertubular tissue, and occasioned probably by the preparation of the section. Fracture of the dentine is capable of reunion.

Cementum. — Of the cementum it will not be necessary to say very much, it possessing the structure of bone and containing both bone cells and Haversian canals; the latter, however, but seldom. (See the figures.)

The quantity of cementum differs in different teeth; in many cases it is very inconsiderable, but it usually increases with age.

In those cases in which there is but a slight development of cementum, a layer of considerable thickness formed of numerous, more or less hexagonal cells, and extending over the whole of that portion of the dentine not covered by enamel, may in most cases be clearly seen.

This layer Mr. Tomes speaks of as a granular layer; it is, however, distinctly and regularly cellular. It is not easy to decide whether it should be regarded as a distinct and permanent structure of the tooth, or whether it merely forms the basement substance in which the cementum is developed; my own impressions incline to the former view.*

A layer of granules, having the aspect of imperfectly developed bone cells, is usually situated apparently between the dentine and cementum, but really in the substance of one or other of these; this layer might well be called the granular layer, and to it the description of Mr. Tomes seems more applicable.

Mr. Nasmyth † describes the cementum as passing over the entire surface of the enamel of the tooth; this would appear, so far as the human tooth is concerned, to be an error. A cellular lamina, however, does really invest the enamel in very young teeth, but this is soon worn away: this layer, however, has nothing to do with the cementum, but is considered by Mr. Tomes to be derived from the inner surface of the membrane of the tooth sac. It may be seen in the teeth of the calf and horse.

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* The following is Mr. Tomes's description of this layer: — "In the intertubular tissue hemispherical or elliptical cells are found, especially near the surface of the dentine of the fang, where they form a layer joining the cement. This in a paper read before the Royal Society I described as the granular layer; on the coronal surface of the dentine they are not numerous. With these cells the dentinal tubes communicate, as do others coming from the cemental cells."

† Memoir read before the Medico-Chirurgical Society by Alexander Nasmyth, Jan. 22d, 1839.

Cementum, is rarely, if ever developed in the pulp cavity, although it has been stated to be so by many observers. The cementum is not unfrequently traversed by tubes, similar to and derived from those of the dentine.

It will now be very evident that dentine and cementum do not differ essentially from each other, and that both are but modifications of ordinary bone.

Enamel.—Examined with an object-glass of one fourth of an inch focus, the enamel exhibits a fibrous appearance. The fibres radiate outwards from the surface of the dentine, somewhat in the same manner as do the dentinal tubes themselves; they are simple, short, somewhat attenuated towards either end, and pass towards the margin of the enamel in a waved manner, sometimes decussating, forming plaits or folds, and this occurs especially when the surface of the dentine is concave. Viewed with a glass of the eighth of an inch focus, they present the appearance of elongated and many-sided crystals, and in transverse sections they are seen to be hexagonal or polygonal; in some instances, however, and especially in the enamel fibres of young teeth, a minute canal may be traced running along each fibre. (See the figures.)

It is uncertain whether each fibre is constituted of a single cell, or whether several unite to form it: the appearance in some cases of faint transverse markings would render it probable that the latter opinion is the correct one.

Near the surface of the dentine linear interspaces may sometimes be noticed between the enamel fibres; with these spaces the tubuli of the dentine frequently communicate, and when they exist in any number, or extend nearly through its entire thickness, they produce a pearly appearance of the enamel, and render it brittle.

Thin longitudinal sections of the enamel in connexion with the dentine generally exhibit numerous linear fractures, which extend through its entire thickness, and which most probably arise from their mode of preparation. Sections of enamel also usually present numerous wavy lines, and which are occasioned by the instrument employed in making the cuttings.

Structure of the Pulp.

The centre of the dentine of all teeth is hollowed out into a cavity; this is occupied with a soft and reddish mass easily separable from the walls of the cavity, the pulp.

The pulp is made up of numerous blood-vessels, the walls of which are constituted of delicate and nucleated cells, of nerves, of ganglionic cells, and larger granular cells placed principally on the surface of the pulp, external to the other structures which enter into its formation.

These external granular cells are supposed to play an important part in the development of the dentine, and to which more particular reference will be made hereafter.

The pain experienced in toothache arises from inflammation of the nerves of the pulp, and which is frequently left exposed to the contact of the air in consequence of the removal of the dentine, by which in sound teeth it is enclosed, as the result of caries.

DEVELOPMENT OF THE TEETH.

The subject of the development of the teeth may be considered under two heads: under the first the general development of the teeth will be briefly noticed, and under the second the special development of their several constituents will be treated of.

Into the various particulars in reference to the general development of the teeth as organs, it would be inconsistent with the design of this work to enter at any length. It will be sufficient to observe that preparations are made for the formation of the milk teeth at a very early period of intra-uterine life; that the first trace of the future tooth is manifest in the form of a papilla placed in the primary dental groove, and consisting of granular and nucleated cells; that around this papilla a membrane is developed, with an open mouth, thus forming a follicle; from the margins of this aperture processes of the mucous membrane, of which the follicle is constituted, are developed, and these uniting with each other close the opening, and convert the follicle into a sac. With the closure of the mouth of the follicle, the first or follicular stage of the development of the teeth is terminated, and the second or saccular stage commences. The number of opercula developed from the margins of the follicles is determinate, being two for the incisives, three for the canines, and four or five for the molars. In the second or saccular stage, the papilla takes the form of the tooth, of which it is the representative, the base dividing in the case of the molars into fangs, and its apex assuming the shape of the crown of the tooth, in the place of which it stands: in this stage also a blastemic matter, consisting of plasma and nucleated cells is developed in the space intervening between the papilla and the sac, and adherent to the inner surface of the membrane of the latter, by which indeed it is generated; lastly, the papillæ become capped with tooth substance or dentine.

With the passage of the teeth through the gums the saccular stage terminates, and the third or eruptive stage is entered upon.

The second or permanent teeth pass through stages precisely similar to those of the first or milk teeth, the papillæ and follicles being developed in crescent-shaped depressions placed in the posterior walls of the follicles of the milk teeth, and which together constitute the secondary dentinal groove.*

Having now obtained a general idea of the development of the teeth, we shall be prepared to understand the mode of development of the individual tissues of the teeth, a subject which has been studied more particularly by Mr. Nasmyth, Professor Owen, and Mr. Tomes.

Formation of the Dentine.—It would appear to be a universal law of development that all animal and vegetable tissues should take their origin in cells; of this law the teeth present a striking and beautiful example.

Thus the dentine is formed out of the cells placed on the formative surface of the papilla or *dentine pulp.* This view of the formation of the dentine originated with Mr. Nasmyth †, and its accuracy has been confirmed by the investigations of subsequent writers, and especially by those of Professor Owen and Mr. Tomes.

Mr. Owen, in his work "Odontography," describes with great minuteness the several steps of the conversion of the cells of the pulp into dentine, and also enters upon the consideration of the development of the other tissues of the teeth.

According to Mr. Owen, the cells of the pulp, which are larger and more numerous on the surface, become arranged in lines which are placed vertical to that surface; subsequent to this arrangement the nuclei are seen to divide, first longitudinally into two portions, each of which becomes a perfect cell, also provided with a nucleus; these again divide, but in a contrary direction, *viz.* transversely; thus four secondary cells are formed within the cavity of the primary cell, and out of its single nucleus. The number is not, however, limited to four, but each nucleus may give origin to many secondary cells. The primary cells are placed end to end, as are also the secondary cells; these last elongate considerably, until at length they coalesce, thus forming the tubes of the dentine; the primary cells remaining as such, and in some adult human teeth being faintly visible. The primary and secondary cells, however, although placed end to end, do not form straight lines, but describe greater and lesser curves, the greater being formed by the primary cells, and the lesser by the secondary; these are the curvatures to which reference has been made in the description of the tubes of the dentine.

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* For further particulars relating to the general development of the teeth consult the admirable paper of Mr. Goodsir, contained in the Edinburgh Medical and Surgical Journal. From the researches of that gentleman we learn that the papillæ of the teeth appear in the upper jaw before the lower; that those of the milk teeth are developed in three distinct divisions, a molar, a canine, and an incisor; that the molar is the first formed, the canine the second, and the incisor the third; also that the first molar is developed before the second, and the first incisor before the second. In the permanent teeth the papillæ, with the exception of the anterior molar, appear at the mesial line first, and proceed backwards.

† Memoir on the Development and Organisation of the Dental Tissues by Alexander Nasmyth, August, 1836.

The views of Mr. Tomes*, although not essentially at variance with those of Professor Owen, yet differ from them in some important particulars. Mr. Tomes describes the primary cells themselves as dividing longitudinally into two or more secondary cells, but not transversely; subsequent to this division each cell elongates, and at length unites with those above and below it, thus forming the dentinal tubes. Sometimes two cells unite with but a single cell placed beneath it, and it is in this way that the branches of the dentinal tubes are produced. Thus, according to Mr. Tomes, the wall of the primary cell, as well as its nucleus, enters into the formation of the dentinal tubuli, while, according to Professor Owen, the nuclei alone give rise to these tubes, the walls of the parent cells not undergoing elongation, but remaining to constitute a considerable portion of the intertubular tissue.

In the human tooth I have been unable to detect the existence of the primary cells of the dentine.

Covering the dentine pulp, a thin transparent membrane exists; this, on its outer surface, is marked with numerous hexagonal depressions, into which the enamel fibres are received.

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* Medical Gazette, Lecture V.

Formation of the Enamel. — Reference has been made to a blastemic matter consisting of nucleated cells embedded in a granular matrix, and situated between the dentine pulp and the inner surface of the sac of the tooth; this is the *enamel pulp*.

The cells of which this is formed are larger than those of the dentinal pulp, more transparent, and with nuclei which are less distinct; they adhere to the inner surface of this sac, which is formed of a process of the mucous membrane of the mouth itself, and from which indeed they are evolved.

This membrane, like all mucous membranes, consists of two layers, an outer basement or fibrous and vascular layer, and an inner colourless and blastemic layer; and it is from this last that the enamel cells proceed. It is marked with depressions similar to those existing on the surface of the membrane of the dentinal pulp, and into which the terminations of the fibres of the enamel are received.

It is out of the cells just described that the enamel fibres are formed, and this in a manner almost similar to that in which the tubes of the dentine are themselves developed; thus the cells are first arranged in vertical lines; these commence in the depressions on the inner surface of the tooth sac, and proceed from without inwards. The cells next elongate until they touch each other by either short or oblique surfaces; some of them coalesce by their extremities, and thus form fibres in which earthy matter is deposited, and which at length terminate in the hexagonal depressions situated on the outer surface of the membrane of the pulp of the dentine.

The nuclei elongate with the cells, and either disappear altogether or else remain as minute cavities running down the centre.

At first the union between the fibres is but slight, so that in newly-formed enamel they may be easily separated from each other when placed in water, to which they will impart a whitish appearance, in consequence of their separation and diffusion through the fluid.

According to Mr. Tomes also numerous spaces exist between the fibres in newly-formed enamel; and it is owing to the presence of these that young enamel owes its opacity and brittleness.

We thus perceive that the enamel is to be regarded rather as a modification of the epithelium than of bone.

The development of both dentine and enamel may be well studied upon the teeth of young pigs, or kittens at the birth.

Formation of Cementum. — The *cementum pulp* is formed between the external surface of the dentine and the internal of the sac of the tooth, it being intimately united to both.

It consists, like the pulps of the other tissues of the teeth, of nucleated cells embedded in a granular matrix: these cells are described by Mr. Tomes * as resembling those of temporary cartilage, being oval in shape and having their long axes placed transversely, and at right angles to the length of the tooth.

The cells nearest the surface of the dentine are the first to become ossified; and when their ossification and development is completed, they form the stellate or bone cells of the cementum. Some consider that the nuclei of these cells alone give origin to the bone cells, and appearances may be observed, even in adult cementum, which are favourable to this opinion.

The cementum is often seen to be traversed by fibres derived from the outer layer of the membrane of the tooth-sac, as well as by tubes prolonged into it from the dentine.

Notice has already been taken of the small hexagonal cells contained in the cementum, and situated principally upon the outer surface of the dentine, and a doubt was expressed whether these were to be regarded as forming a part of the structure of the cementum, or whether they constituted a distinct organisation.

The cementum is particularly liable to an increased and abnormal development constituting exostosis.

It would thus appear, on the one hand, that the cementum and dentine are but modifications of each other, and also of one and the same tissue, the osseous; while on the other, it is evident that the enamel is a modification of the epithelium.

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* See Lecture V.

Mr. Nasmyth describes the cementum as passing over the crown of the tooth and surface of the enamel, in a thin layer composed of hexagonal cells and fibres; this layer exists only on the surface of the enamel of the young teeth of the human subject, and it is not composed of dentine, but consists of either a few of the unelongated cells of the enamel pulp, or, as Mr. Tomes considers, of the inner surface of the sac of the tooth.

Nature of Caries of the Teeth.

Various opinions have been entertained in reference to the nature of the peculiar decay denominated caries, to which the teeth are so liable. Some have supposed that it is a vital process resulting from inflammation. The fact that dead teeth, that is, teeth which have been removed from the jaw and are again employed as artificial teeth, undergo a similar decay to that which affects the living teeth, proves that it is not essentially a vital action, although it cannot be questioned but that the condition of vitality and the state of development of the teeth must exert a powerful influence over the progress of the decay. Other observers regard the decay of the teeth as a purely chemical phenomenon, the earthy matter of the teeth being removed by the action of free acid in the saliva: this view of its nature certainly explains many of the circumstances connected with dental caries, and is supported by the fact already cited, *viz.* that dead teeth are susceptible of the change.

Two facts, however, require to be determined before the chemical theory of the decay of the teeth can be considered to be proved; first, that the saliva is in every case of dental caries really acid; and second, that the portion of the tooth which is subject to the carious action is really dead: upon both of these points considerable doubts may be entertained.

For myself I have long entertained the idea that the real and proximate cause of the decay of the teeth was to be found in the presence of some parasitical production, and that the condition of vitality of the teeth and of the states of the saliva were to be considered merely as predisposing causes to the affection.

This idea acquires some confirmation from an examination of the carious matter of a tooth; in it vast quantities of minute threads or filaments, possibly those of a fungus, are invariably to be discerned, as well as numberless dark granules and irregular masses bearing in some cases the aspect of true cells.

The question may be asked, are these threads, granules, and cell-like masses any thing more than the decomposing elements of the dentine, in which tissue it is that the chief ravages of the decay occur? The answer is, possibly not; but the surprising numbers of these filaments and the testimony of Mr. Tomes are opposed to the idea that they are the remains of the tubes of the dentine. Mr. Tomes thus writes in his tenth Lecture in reference to the tubes of the dentine:—"A transverse section of carious dentine, rendered soft like cartilage from the loss of its lime, presents a cribriform appearance. The tubuli seem enlarged and rather irregular, quite unlike the figure they present in healthy dentine: this would indicate that the solvent enters and acts upon the parietes of the tubes previous to affecting the intertubular tissue, and that the parietes of the tubes are therefore the first to disappear. I feel quite certain that in the cases I have examined, and they are numerous, the parietes of the tubuli, so distinguishable in healthy dentine, have almost, if not wholly, disappeared with the removal of the lime."

Nature of Tartar on the Teeth.

Tartar of the teeth consists of phosphate of lime mixed up with the mucus of the mouth and epithelial scales: it contains also occasionally animalcules and vegetable growths, which find in the animal matter of the tartar a convenient nidus for their development. The accumulation of tartar around the necks of the teeth results from an opposite condition of the saliva to that to which chemists ascribe dental caries, *viz.* an alkaline state of it.

ART. XVII. CELLULAR OR FIBROUS TISSUE.

THE truth of the scientific dictum that every living thing proceeds from a germ or ovum is now generally admitted, and so also it may be said that each portion of the fabric of such living entity takes its origin in a cell, the early and embryonic condition of every organ and structure being reducible to that of a cell.

It was not, however, this consideration that induced the older anatomists to apply the term cellular to the tissue about to be described, they having but little knowledge of the structure of the elementary cell, or of its universal presence.

They were led to denominate the tissue, into the description of which we are about to enter, cellular, in consequence of observing the areolæ or spaces left between the fibres of which it is composed, and which they erroneously considered to be cells. The cellular tissue, then, though like all other tissues, taking its origin in cells, inasmuch as in its fully developed state it consists of fibres, would be more accurately denominated the fibrous tissue, as indeed by many modern anatomists it really is: the term cellular tissue is, however, one of so ancient a date, and one, moreover, in such general use, and so well understood, that it seems to be scarcely advisable to abandon the use of it altogether.

The cellular or fibrous tissue, however, as ordinarily encountered, is constituted not of a single description of fibre, but consists of two kinds intermingled in different proportions, and each of which is possessed of distinct characters and properties.

The most remarkable difference between the two descriptions of fibrous tissue is, that the one is white and inelastic, and the other yellow and elastic: each of these will be described under different heads, and the former before the latter.

INELASTIC OR WHITE CELLULAR OR FIBROUS TISSUE.

Tendons, Ligaments, Membranes, &c.

The inelastic fibrous tissue is very generally distributed throughout the body: it constitutes the principal portion of tendons, ligaments, and fasciæ; of the fibrous membranes, the dura mater, pericardium, periosteum, perichondrium, tunica albuginea of the testicle, and sclerotic coat of the eye; also of the serous, synovial and mucous membranes, as well as of the skin, and it forms likewise the principal constituent of the loose cellular tissue which is so abundantly developed throughout every tissue and organ of the body, but which is invariably present in large quantities wherever motion is necessary, as in the axilla, between the fasciculi of muscles, and in the course of the vessels.

When endowed with a distinct form, as in the case of the tendons, it may be called *morphous* inelastic cellular tissue, and when it has no circumscribed shape, the term *amorphous* may be applied to it: when constituting membrane, it exists in the state of *condensed* fibrous tissue; and when it merely binds organs together, or allows of the motion of parts, it may be called loose or *reticular* cellular tissue.

There is, however, a form of the inelastic fibrous tissue which requires not merely a separate name, but a distinct notice. This form is met with in the great omentum, and consists in the fact of spaces of irregular size and form being left between the fibres, and hence it may be termed *areolar cellular tissue.* The best examples of it are met with in the omenta of children and lean persons, which contain but little fat. (See Plate XL. *fig.* 4.)

The inelastic cellular tissue is made up of innumerable unbranched threads or fibres of equal calibre, of great tenuity, which appear white to the unassisted sight, but of a yellow colour when viewed under the microscope, and which have a great disposition to assume a waved or zigzag arrangement, the folds formed being comparable to those in which a loose skein of silk is often observed to fall. (See Plate XXXIX. *fig.* 6.)

When dried, the inelastic cellular tissue assumes the transparent appearance and consistence of horn: in water the fibres swell up somewhat, become opaque and white, but still preserve their form: in acetic acid they swell up greatly, become indefinable, soft, and gelatinous: the addition of a mineral acid will, however, bring the fibres again into view.

The remarkable effect of acetic acid on the inelastic fibrous tissue has suggested the idea to Mr. Bowman that "it is rather a mass with longitudinal parallel streaks (many of which are creasings), and which has a tendency to slit up almost *ad infinitum* in the longitudinal direction."

There are several considerations which may be urged in disproof of this view; the first is, the mode of development belonging to this tissue; the second, the fact that the fibres are all of nearly an equal diameter; and the third is, that the tissue still retains its fibrous constitution even after the application of acetic acid.

The white fibrous tissue is employed wherever a strong and inelastic material occupying but little space is required.

A degree of elasticity not unfrequently appears to belong to this tissue; but this is rather apparent than real, and depends upon the extent of its admixture with the next form of fibrous or cellular tissue to be described, viz. the elastic. (Plate XXXIX. *fig.* 7.)

ELASTIC CELLULAR OR FIBROUS TISSUE.

The elastic cellular or yellow fibrous tissue is distinguished from the inelastic form by its branched filaments, the diameter of which is unequal, its elasticity, its deeper colour, and the absence of any appreciable effect on the addition of acetic acid. (See Plate XL. *fig.* 1.)

Like the inelastic fibrous tissue, it rarely occurs in an unmixed form, being mostly intermingled with it in variable proportions: thus it is encountered in tendons, ligaments, and, indeed, in all forms and conditions of the inelastic cellular tissue; it constitutes the principal portion of the ligamenta subflava and nuchæ, of the transverse fascia of the abdomen, of the cricothyroid and thyrohyoid membranes, of the chordæ vocales, of the internal lateral ligament of the lower jaw, of the stylo-hyoid ligaments, of the middle coat of the arteries, and of the membrane uniting the rings of the trachea and its ramifications. It is also met with in considerable quantities beneath the mucous membrane of the esophagus, at the base of the epiglottis, in maintaining which in the erect position it is probably mainly instrumental, in the lungs and in the integuments of the penis.

The elastic cellular tissue presents some differences of appearance and structure, in certain of the situations in which it is encountered: thus, in the tendons and in the smaller blood-vessels (Plate XL. *figs.* 1, 2, 3. 5.) the fibres are very slender, appear to be but little branched, and contain at intervals nuclei in the same manner as do the fibres of unstriped muscles; in the reticular cellular tissue again, they are slender, unbranched, and without nuclei (see Plate XXXIX. *fig.* 7.); in the ligamenta flava and nuchæ, in the cricothyroid and thyrohyoid membranes, the fibres are thick, much branched, curled, and interwoven, but they do not present nuclei (see Plate XL. *fig.* 1.); in the larger arteries, the fibres are slender, and are united together so as to form areolæ (see Plate XL. *fig.* 2.), while in the smaller blood-vessels they are distinctly nucleated, as already observed.

There is little doubt but that the several forms of elastic tissue just described do really represent different stages and states of the same structure; and it will be observed, that some of them, and especially that of the small blood-vessels, approach very closely in structure and appearance to that of unstriped muscular fibre: the fibres of the former differ, however, in being sparingly branched, and in their more slender diameter.

It is not easy, without the addition of re-agents, to distinguish the two forms of fibrous or cellular tissue from each other when mixed together: nevertheless, when the two are well separated, the elastic fibres may be frequently singled out from the inelastic, in consequence of their presenting a darker and stronger outline, as well as of their following a more curled and tortuous course. (See Plate XXXIX. *fig.* 7.) Acetic acid applied to a portion of mixed cellular tissue, at once allows the elastic fibres to be clearly seen, rendering the inelastic fibres transparent, and almost invisible.

There are several parts of the human organisation described by modern minute anatomists and physiologists as being in part composed of unstriped muscular fibre; these are the skin, dartos, nipple, clitoris, penis, the ducts of the larger glands, as the ductus communis choledochus, the ureters, and vasa deferentia. Now, I find that all these parts, which I have examined with care, owe their contractility, and their power of erection, to the presence of the nucleated form of the elastic tissue which has been described as existing in tendons and the smaller blood-vessels, and not to any form of muscular fibre; and further, that in the majority of them, and especially in the dartos, penis, clitoris and nipple, this elastic tissue is confined almost entirely to the blood-vessels, the walls of which it constitutes: this fact may be readily ascertained in the instance of the dartos by taking a small fragment of that membrane when in a fresh condition, and having spread it out on the surface of a piece of glass without the addition of any fluid, then submitting it to the microscope, when the number, size, and course of the blood-vessels may be traced, and the disposition of the intervening fibrous inelastic tissue recognised: in the recent state, however, the vessels are filled with blood, the presence of which prevents the satisfactory detection of the elastic constituent of the blood-vessels: if now, however, acetic acid be applied to the fragment of membrane thus spread out, the inelastic fibrous tissue will become indistinct, the red blood corpuscles contained in the vessels will be dissolved, and the tissue of the blood-vessels clearly brought out. (Plate XLIII. *fig.* 3.)

The extent of contraction of which the dartos is susceptible is very great, and the act of contraction must of course exert a very powerful influence over the circulation of the blood in its vessels. In the contracted state of this membrane the slender fibres of the elastic tissue as well as their nuclei are frequently curled up in a spiral manner, an arrangement by which any amount of shortening may be secured.

The contraction of the tissue of the dartos, and indeed of all elastic tissue, is evidently not a physical, but a vital act: this is shown by the relaxation and contraction which it experiences in sympathy with the condition of the vital powers, as well as with any causes, as heat and cold, which affect these powers.

The corpora cavernosa penis and corpus spongiosum urethræ are almost entirely composed of blood-vessels, and the peculiarity of these parts consists in the large size of the vessels and in their repeated inosculation. (Plate XLIII. *fig.* 4.)

In the lungs, the blood-vessels are so numerous, that they, in this case, also constitute the principal portion of the fabric of these organs: — this may be beautifully seen in the lungs of the lower reptiles, as the triton and frog.

Henle has described a peculiar arrangement of the fibres of elastic tissue. "I have already said," he remarks, "that the fibres of the cellular tissue are for the most part united into a number more or less considerable, and thus form flattened bands of different thickness. These bands unite in their turn to produce others larger, or even membranes, and thus sometimes they apply themselves parallelly to each other; at others, they cross each other in the most varied directions. When the cellular tissue fills the interstices of organs under the form of a soft mass, easy to displace, and extensible, the bundles may be perceived without the least preparation, seeing that they cross and interlace in all directions, and that even to the naked eye they represent a network of delicate fibres. The size of the bundles, which I call primitive bundles, or after their origin, the fibres of the cells of cellular tissue vary from the 0·003 to the 0·006 of a line. The majority of the primitive bundles are deprived of special envelope: the fibres may easily be detached, the one from the other, and separate, when one bends a bundle strongly. But in many situations they are interlaced, and held together by filaments, which differ from the fibres of cellular tissue by their chemical and microscopical peculiarities, while in certain respects they approach the fibres of elastic tissue; of which we shall give a description further on. They are almost still finer than the fibres of cellular tissue, quite flat and homogeneous, but with outlines much more obscure, and they are distinguished, above all, by the considerable folds, which they describe when they are in a state of separation. In order to recognise them, it is necessary to place the cellular tissue in contact with acetic acid: in this acid the bundles of cellular tissue become transparent, swell, and cease to appear fibrous, while the filaments which envelope them undergo no change. In this manner it happens that a bundle, which appears to be composed of the ordinary interlaced fibres of cellular tissue, comports itself after having been treated with acetic acid, as a transparent cylinder divided by contractions often very regular, and which one soon observes to be caused by a filament which runs spirally around the bundle; or also by separated rings placed at a greater or less distance from each other. I have rarely succeeded in reducing the turns to a single filament, and I am obliged in consequence to leave undecided the question, whether it does not sometimes happen that many filaments are rolled spirally around a bundle. The formations which I have described show themselves in no part in a more beautiful manner than in the delicate and firm cellular tissue, which is situated at the base of the brain beneath the arachnoid, between the vascular trunks and the nerves, and which becomes distended into isolated filaments, on extension, as for example, in any part of the circle of Willis. There I have never sought the spiral filaments in vain; nevertheless analogous bundles, encircled with spirals, may be seen also upon other parts of the economy, in serous membranes, in the subcutaneous cellular tissue, in the skin, and even in the tendons."*

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* Anat. Gen. vol. i. pp. 377, 378.

It appears to me that Henle has misunderstood the structure, and consquently the nature of the formations noticed by him: there can be little doubt but that these, in place of being bundles of filaments composed of inelastic fibrous tissue encircled with a spiral coil of elastic tissue, are in reality hollow cylinders, vessels in fact in progress of formation, consisting of, in the stage described by the German physiologist, an inner transparent and apparently structureless tunic, enclosed in a coil of elastic fibrous tissue.

The correctness of this view is established by the very convincing fact, that the tubular formation in the condition just described may be traced up to the state of perfect blood-vessels, some of which may also now and then be seen dividing into branches, and containing, moreover, blood corpuscles. Several of the stages of the development of these vessels are seen in Plate XL. *fig.* 3.

DEVELOPMENT OF CELLULAR TISSUE.

Exact observations are still required on the subject of the development of both the elastic and the inelastic forms of the cellular or fibrous tissue, and especially of that of the latter form. Schwann and all other observers after him have described the cellular tissue as taking its origin in cells of an elongated form, from the extremities of which fibres, mostly branched, proceed, the cells themselves ultimately becoming absorbed: microscopists, however, have not as yet attempted to point out the differences which doubtless exist in the development of the two forms of cellular tissue, but have for the most part contented themselves with the above general description.

It appears to me that the observations already made on the development of the cellular tissue apply only to the yellow or elastic kind; and to this conclusion I am led by the fact that observers describe the elongated nuclei as giving origin to *branched* filaments; and we know that the fibres of the inelastic fibrous tissue are simple, and not branched.

According to my observations, both forms of cellular tissue originate in cells.

The cells of the white fibrous tissue exist first as rounded nuclei, around which the cell wall gradually makes its appearance, and these cells when fully formed are large, granular, elongated, fusiform, and from each extremity at length proceeds a single *unbranched* thread, which gradually becomes extended into a filament or fibre, which is produced by the growth and extension of the cell wall itself, and the extremity of which unites for the production of an elongated thread with that proceeding from the other cells placed above and below it: finally, the process terminates by the absorption of the nuclei. (See Plate XLIII. *fig.* 2.)

The cells of the yellow fibrous tissue also exist, at first as nuclei, then as fusiform cells, but differ from those of the white fibrous tissue in the subsequent steps of their development, in that the cells are disposed in lines, each fibre being formed, as is the case with the unstriped muscular fibre, by the union of the filaments, proceeding from each series of linearly disposed cells, and in that the filaments proceeding from the cells are very frequently *branched.* (See Plate XXXIX. *figs.* 1, 2. Plate XL. *figs.* 3. 5.)

The above described mode of development may be followed out in longitudinal and cross sections of tendon treated with acetic acid, also in the smaller vessels of the pia mater, and in those placed in the mixed cellular tissue which separates the different striped muscular fasciculi: we thus perceive, that in the case of the yellow fibrous tissue, many nuclei are required to form a single filament; and further, that there is a strong analogy in the mode of its development with that of muscular fibre, as also in the physical properties of the two tissues.

In the fibrillation of the fibrin of the blood we have an example of the formation of filaments independently of any development from cells, and at one time I conceived that the fibres of the white fibrous tissue might possibly originate in a similar manner.

Art. XVIII. MUSCLE.

Few of the animal tissues have been more extensively examined than the muscular: the multiplied observations made on its structure have, however, led neither to that uniformity of opinion respecting it, nor, indeed, to that accurate knowledge of its minute anatomy which might have been anticipated; of the truth of this position, evidence will be shortly adduced.

Muscles admit of division into the *voluntary*, or those which are under the control of the will, and the *involuntary*, or those of which the action takes place independently of the will; the former consist of the muscles of *animal life*, those, for example, of locomotion, and the latter embrace those of *organic life*, as the muscles of the alimentary canal (the sphincters of the œsophagus and anus excepted, which are to a certain extent voluntary), the heart, the uterus, the bladder, &c.

It will be observed, that the involuntary muscles, or those of organic life, usually encircle the hollow viscera: there are some other situations, however, in which involuntary muscular fibres are met with, as in the trachea and its bronchial ramifications, the iris, the sarcolemma, and, according to some observers, as Bowman, they are also encountered in the dartos and covering the excretory ducts of the larger glands, as the ductus communis choledochus, the ureters, and vasa deferentia; and it is with them a matter of question how far the contractility of the skin, and the erection of the penis, clitoris and nipple, may be dependent upon the presence of involuntary muscular fibrillæ. In the preceding article I have, however, shewn that the contractility of these parts depends upon the presence of a nucleated form of elastic tissue allied to unstriped muscular fibre in many of its properties, but yet distinct therefrom.

Corresponding with the division of muscles into voluntary and involuntary, there exist differences of structure: thus, the muscles under the control of the will are all *striped,* while those which are not under its influence are *unstriped.* To this rule, however, one remarkable exception may be mentioned, viz. the muscles of the heart, the action of which is to a great extent involuntary, and which are yet striped: this exception is rather apparent than real, as will be seen hereafter.

STRUCTURE OF MUSCLE.

A striped muscle is made up of a number of unbranched fibres, each of which is included in a distinct sheath, the *sarcolemma,* and consists of a number of threads or fibrillæ: the fibres again are collected into sets or bundles called *lacerti;* these are held together, and yet separated by a mixed form of cellular tissue, which also contains fat vesicles blood-vessels, and nerves.

An unstriped muscle consists of fibrillæ, intermingled with fibrous tissue: these do not form fibres, and consequently there is no sarcolemma.

Between striped and unstriped muscle there is no essential or specific structural difference: the one is not to be regarded as typically distinct from the other, but both should rather be considered as different conditions in the development of one and the same tissue. Of this position, evidence will be hereafter adduced.

According to the above view, muscular fibre presents two grand stages of development; the first of which is represented by the unstriped fibrilla, and the second by the striped muscular fibre.

We shall first describe the structure of the unstriped muscular fibrilla, because it represents an earlier condition of development than the striped.

Structure of Unstriped Muscular Fibrillæ. — Unstriped muscles consist of fibrillæ which are unbranched, rather broad, somewhat flat, and which contain imbedded in their substance, elongated, and granular nuclei. (See Plate XLI. *fig.* 2.)

The fibrillæ usually run parallel to each other, and form thin layers and fasciculi, which are separated from each other by cellular tissue, and frequently interlace.

The nuclei are sometimes imbedded in the substance of the fibrillæ, without at the same time increasing their diameter: at others they render the fibrillæ ventricose from their great size; and again, in other cases, they protrude from their sides. (See Plate XLI. *fig.* 2.) They are best seen after the addition of acetic acid.

Unstriped muscles are doubtless freely supplied with blood-vessels and with nerves.

The unstriped muscle is called into action with greater difficulty than the striped; its action is also slower, and of a peculiar kind, giving rise to the vermicular and peristaltic motion, seen especially in the intestines.

This slower and less energetic action results from its lower degree of organization.

The muscular structure of the heart, the action of which is to a considerable extent involuntary, requires a special description. The muscular tissue of this organ has been usually supposed to constitute an exception in its structure to that of other involuntary muscles, and that while it performed the office of an involuntary muscle, it yet possessed the structure of a voluntary muscle, its fibres being striped.

Mr. Bowman, one of the very best authorities on the structure of the muscular fibre, gives the following description of the tissue of the heart. "The cross stripes on the fibres of the heart are not usually so regular or distinct as in those of the voluntary muscles. They are often interrupted, or even not visible at all. In some of the lower animals their sarcous elements never form transverse stripes. These fibres are usually smaller than the average diameter of those of the voluntary muscles of the same subject by two-thirds, as stated by Mr. Skey." *

This description is very imperfect, and in some respects, according to my observations, incorrect. Thus, the muscular substance of the heart does not form fibres at all, but consists simply of fibrillæ, which agree in every respect with those of other involuntary muscles, save in their transverse striation: thus they have the same considerable diameter: they are, in like manner, abundantly nucleated (see Plate XLI. *fig.* 3.), and they have the same arrangement, interlacing with each other, and not forming fibres included in a sarcolemma, as is the case with the voluntary muscular tissue. The transverse striæ, too, have not the deep and permanent character belonging to the fibrillæ of ordinary striped muscle, as is evinced by the fact that acetic acid effaces all vestige of striation.

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* Physiological Anatomy, p. 161.

It thus appears that the muscles of the heart agree in structure much more closely with that of other involuntary muscles, which is contrary to what is generally supposed, than they do with that of the voluntary muscles.

Thus then the structure and the function of the muscles of the heart are in accordance, and not in antagonism, as is usually conceived, the single point of difference between its fibrillæ and those of other involuntary muscles consisting in the feeble transverse striation, the presence of which evinces a somewhat higher degree of development, as well as a greater power of contractility.

Structure of Striped Muscular Fibre.— The striped muscle consists of fibres: each of these is included in a distinct envelope, termed Sarcolemma, and is made up of a number of lesser fibres or fibrillæ. (See Plate XLII. *fig.* 1.)

The fibres vary very considerably in size, not merely in different animals, but also according to the age of an animal, and even in a single bundle of the same animal, some of them being three or four times larger than others, and the smaller being usually adherent to the larger fibres; a fact which has reference to the development of muscular tissue, and which will be explained when we arrive at the consideration of that portion of our subject. (See Plate XLII. *fig.* 4.) The difference in the size of the fibres according to age is very remarkable, those of the fœtus being several times smaller than the fibres of the adult. (See Plate XLII. *fig.* 1. and Plate XLIII. *fig.* 1.)

They differ also to a very considerable extent in form as well as magnitude: thus, in a cross section and in a recent state they are seen to be more or less angular and compressed, but still preserving, in most cases, much of the character of cylinders. In the dry condition this angularity is greatly increased, and to this state of the fibres the representations hitherto given chiefly refer. (See Plate XLII. *fig.* 5.)

The fibres, both great and small, are, as already observed, arranged in bundles or lacerti, of variable size; those of the same bundle run parallel to each other, and the different bundles are separated, and yet held together by mixed fibrous tissue.

Examined with a moderate power of the microscope, each fibre is seen to exhibit numerous transverse striæ, which are placed at tolerably regular distances from each other: some fibres, also, and especially such as have been preserved in spirit, present numerous fainter longitudinal striæ.

When viewed with a somewhat higher object glass, and when each fibre has been torn into pieces by needles, its entire bulk will be seen to be made up of a number of slender threads of equal diameter, which present a distinct transverse striation.

It was formerly very generally supposed that the transverse lines on the striped muscular fibre were produced by a filament which wound spirally around it: this notion is, doubtless, erroneous, as indeed it is now generally allowed to be.

It has been observed that the fibrillæ are themselves marked with transverse striæ: now it is not difficult to convince oneself that the striation of the fibre is produced by the striæ of the fibrillæ, the striæ of one fibrilla corresponding with that of another, and thus giving rise to a line which extends entirely across the diameter of the fibre.

The correctness of this explanation might have been easily inferred from a knowledge of the composition of the striated muscular fibre of banded fibrillæ, and from the aspect of the transverse line itself, which, when examined with a high power of the microscope, does not present the appearance of an uninterrupted and continuous line, such as would be produced by the winding of a filament around it, but rather of a line formed by the apposition of a series of dots or shorter lines; in which manner, indeed, it is that the striation of the fibre is really produced, as we have seen.

The fibrillæ contained in each fibre are unbranched, of great tenuity, of nearly equal diameter (see Plate XLII. *fig.* 1.), and their number varies greatly, amounting in the larger fibres to as many as fifty or sixty, while in the smaller they may not exceed from one to five and upwards, according to the breadth of the filament.

The striæ present a very uniform and strongly marked character: the spaces between them are not, however, equal: thus, they are sometimes rather longer than the diameter of the fibrilla: at other times, they are shorter, and when the striæ are very close, the fibrilla becomes ventricose or moniliform.

Much difference of opinion prevails as to the nature of the striation exhibited by the fibrillæ. Drs. Sharpey * and Carpenter † incline to the opinion that each fibrilla consists of a series of particles or cells cohering in linear series, and that the lines indicate the point of junction of these; Mr. Erasmus Wilson ‡ attributes a still more complicated structure to the striated fibrilla. He believes that two kinds of cells exist in each fibrilla; a pair of light cells separated by a delicate line, being interposed between each pair of dark ones.

Lastly, Bowman considers that the lines indicate the divisions between particles, which he denominates "sarcous elements."

My own view of the nature of these lines differs from that of all the gentlemen named. I consider that the lines in question are produced by the simple corrugation or wrinkling of the threads at regular distances: a view, the accuracy of which is all but proved by a consideration of the development of muscular fibre, and by the action of acetic acid on the fibrillæ of the heart, the transverse markings of which it entirely obliterates.

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* Quain's Anatomy, 5th edition, vol. ii. p. 168.

† Human Physiology, p. 176.

‡ Manual of Anatomy, 3d edition, p. 16 .

The fibrillæ are, as already stated, included in a sheath, the sarcolemma of Bowman, both together constituting the fibre. The sheath cannot at all times be seen: it may, however, frequently be so, and especially when the fibrillæ have been torn across, the sheath at the same time not having been divided, its greater elasticity enabling it to resist the force which was sufficient to rupture the muscular fibrillæ. It is in such cases that the best view of this membrane is obtained. (See Plate XLII. *fig.* 1.)

Treated with acetic acid, each fibre discloses most distinctly a considerable number of elongated and granular nuclei, the outlines of which are in some cases visible, even without the application of the acid. (See Plate XLII. *fig.* 2.)

Of these nuclei, Mr. Bowman remarks: "In the fully formed fibre if it be large, they lie at various depths within it; but if small, they are at or near the surface. They are oval and flat, and of so little substance, that though many times larger than the sarcous elements, and lying amongst them, they do not interfere with their mutual apposition and union." "It is doubtful whether the identical corpuscles, originally present, remain through life, or whether successive crops advance and decay during the progress of growth and nutrition: but it is certain that as development proceeds fresh corpuscles are deposited, since their absolute number is far greater in the adult than in the fœtus, while their number relatively to the bulk of the fibre at these two epochs remains nearly the same." *

The above description is in part only correct. Thus I find, first, that the nuclei are invariably situated on the external surface of the fibre, the majority within the sheath, and either adherent to this, or to the exterior fibrillæ, some also being placed on the outer surface of the sarcolemma; facts which throw much light upon the development of the muscular fibre; secondly, that the nuclei are not usually free nuclei, but are contained in most cases in filaments in every way similar to those of unstriped muscle, and with which they are identical.

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* Physiological Anatomy, vol. i. pp. 158, 159.

Were the nuclei really scattered throughout the substance of a muscular fibre, they would infallibly destroy the parallelism of the striæ, and greatly interfere with its contractile power.

The interpretation to be given of the location of the nuclei and fibres of unstriped muscle in the situations indicated will be explained when the subject of the development of muscular fibre is considered; at the same time, also, the point raised by Mr. Bowman as to the persistence of the nuclei will be discussed.

The fibres of the upper part of the esophagus are striped while those of the lower half are unstriped. It has been considered a matter of uncertainty whether the two pass by insensible gradations of structure into each other, or whether they terminate abruptly. I believe, after careful examination, that the latter supposition is the correct one.

With a few remarks upon the peculiar views entertained by Mr. Bowman, in reference to the structure of the striated muscular fibre, the discussion of the structure of muscle may be brought to a conclusion.

"It was customary," writes Mr. Bowman *, "both before and since his time (the time of Fontana), as at the present day, to regard the fibre as a bundle of smaller ones, whence the term *primitive fasciculus,* first given to it by him, and adopted by Müller: but this view of the subject is imperfect. The fibre always presents, upon and within it, longitudinal dark lines, along which it will generally split up into fibrillæ; but it is by a fracture alone that such fibrillæ are obtained. They do not exist as such in the fibre. And further, it occasionally happens that no disposition whatever is shown to the longitudinal cleavage; but that, on the contrary, violence causes a separation along the transverse dark lines, which always intersect the fibre in a plane perpendicular to its axis. By such cleavage discs, and not fibrillæ, are obtained, and this cleavage is just as natural, though less frequent, than the former. Hence it is as proper to say that the fibre is a pile of discs as that it is a bundle of fibrillæ: but, in fact, it is neither the one nor the other, but a mass in whose structure there is an intimation of the existence of both, and a tendency to cleave in the two directions. If there was a general disintegration along all the lines in both directions, there would result a series of particles, which may be termed *primitive particles*, or *sarcous elements*, the union of which constitutes the mass of the fibre. These elementary particles are arranged and united together in two directions. All the resulting discs as well as fibrillæ are equal to one another in size, and contain an equal number of particles. The same particles compose both. To detach an entire fibrilla is to abstract a particle of every disc, and *vice versâ*. The width of the fibre is therefore uniform, and is equal to the diameter of any one of its fibrillæ, and is liable to the greatest variety."

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* Physiological Anatomy, vol. i. pp. 151, 152.

This view of the structure of the striated muscular fibre is ingeniously conceived and well expressed; nevertheless it can be shown, I think, notwithstanding its ingenuity, to be incorrect.

There are two considerations which appear to me to be sufficient to disprove the view just propounded. The first is, that the rudimentary muscular fibre consists of one or more threads or fibrillæ, containing imbedded in them a number of elongated nuclei, which, however, have no correspondence with the transverse markings; and the second is, that, while any muscular fibre may at any time be readily separated into its component fibrillæ, the simultaneous transverse cleavage spoken of and figured by Mr. Bowman is an occurrence of extreme rarity, and one, moreover, of which I have never been able to perceive the slightest trace in any muscular fibre which has fallen under my notice.

It would thus appear that the older view is the correct one, and that the striped muscular fibre is made up, as already described, of a variable number of fibrillæ enclosed in a tubular sheath.

Blood Vessels of Muscles. — Muscles are copiously supplied with blood vessels: the larger vessels are contained in the cellular tissue separating the fascicles or lacerti of the muscles, and which serves to support and to conduct them; the smaller vessels or capillaries are not encircled by cellular tissue, but penetrate between the fibres, forming numerous capillary loops and meshes, having their long axes disposed in the direction of the length of the fibres. This arrangement of the capillaries is shown in Plate XLI. *fig.* 4.

Much of the colour of a muscle arises from the blood enclosed in the vessels, but not all, a portion of it being contained in the muscular fibres themselves.

It is evident that the contraction of the fibres exercises much influence upon the capillary circulation, reducing the calibre of the capillaries to such an extent as that the blood corpuscles can pass through them only in an elongated form.

In the course of the larger vessels, imbedded in the interfascicular cellular tissue, fat corpuscles are often abundantly distributed, as represented in Plate XLI. *fig.* 1.

Nerves of Muscles. — Muscles are also abundantly supplied with nerves, principally those of locomotion. Burdach has figured and described the nerves in muscles as forming loops, which either join other neighbouring loops or else return into themselves. The figure and description given by Burdach have been adopted by almost all succeeding anatomists; notwithstanding which, I would observe, that I have never seen the nerves terminating in muscle in the manner indicated; not, however, that I doubt the fact of their doing so, because such a mode of termination is common to nerves; but would simply infer from this, that the loop-like arrangement is neither very general nor very obvious.

According, then, to the latest physiologists, nerves, strictly speaking, really have no termination whatever in muscles: an opinion the accuracy of which is more than doubtful.

I find that the nerves, after branching in a dichotomous manner, have a real termination, and that from time to time certain tubules leave the main trunks, and end in the formation of elongated and ganglioniform organs situated between the fibres of muscle. (See Plate XLI. *fig.* 4.)

UNION OF MUSCLE WITH TENDON.

The unstriped muscular fibrilla is rarely if ever attached to tendon or aponeurosis: the striped fibre, on the contrary, is almost constantly so.

Two errors have prevailed in reference to the union of the striated muscular fibre with tendon.

The first has reference to the form of the extremity of the fibre in connexion with the tendon; the second to the precise mode of junction between the two.

Thus most observers have described and figured the fibre as terminating in a conical point, from which the fibres of the fibrous tissue of the tendon proceed in a straight line.

This description is contrary to fact, both as respects the form of the fibre and its mode of union with the tendon: muscular fibre is rarely, if ever inserted vertically into a tendon or aponeurosis; but in all the instances which have fallen under my observation, the insertion has been either oblique or occasionally at right angles with the tendon; the extremity of the fibre being in the one case also oblique, and in the other truncate: this termination is the very opposite of that usually attributed to it. Let us next see in what way the two structures are united. In no one instance have I ever seen the fibres of the fibrous tissue of the tendon unite themselves directly with the muscular fibre: on the contrary, the mode of junction has always been effected in the following manner: — the sheath of each fibre is prolonged upon the surface of the tendon where the union is oblique, and certain of the fibres of the tendon are extended upon and interlace with the terminal portions of the muscular fibres and their investing sheaths. (See Plate XLII. *fig.* 4.)

MUSCULAR CONTRACTION.

Many attempts have been made to determine the exact changes which the muscular fibre undergoes in its passage to a state of contraction: these attempts do not appear to me to be altogether satisfactory and successful.

The earliest opinion formed in reference to muscular contraction supposed that, during contraction the fibres and fibrillæ of muscle are disposed in a zigzag manner, such a disposition of the fibres of course having the effect of materially shortening the muscle. (Plate XLIII. *fig.* 5.)

The advocates of this view seem to have overlooked the fact that fibres thus disposed, having no fixed or direct points from which to act, would have their power by such an arrangement rather diminished than increased: this idea has therefore been justly discarded, and an account of the nature of muscular contraction, much more closely approximating to the truth, substituted in its place.

Mr. Bowman, who has written by far the best account of muscular contraction which has yet appeared, discriminates between passive and active contraction of muscle: the former he conceives to be a uniform act, involving and affecting equally the entire mass of the muscle: the latter, on the other hand, he considers to be a partial act, implicating, first, a particular part or parts of a fibre; subsequently leaving these, and advancing to other and neighbouring parts of the same fibre.

This view is founded principally upon the experiment detailed below, made upon a fibre of the claw of a crab, which still retained its contractility. "In an elementary fibre from the claw, laid out on glass, and then covered with a wet lamina of mica, the following phenomena are always to be observed. The ends become first contracted and fixed. Then contractions commence at isolated spots along the margin of the fibre, which they cause to bulge. At first they only engage a very limited amount of the mass, spreading into its interior equally in all directions, and being marked by a close approximation of the transverse stripes. These contractions pull upon the remainder of the fibre only in the direction of its length; so that along its edge the transverse stripes in the intervals are very much widened and distorted. These contractions are never stationary, but oscillate from end to end, relinquishing on the one hand what they gain on the other. When they are numerous along the same margin, they interfere most irregularly with one another, dragging one another as though striving for the mastery, the larger ones continually overcoming the smaller; then subsiding, as though spent, stretched by new spots of contraction; and again, after a short period of repose, engaged in their turn by some advancing wave. This is the first stage of the phenomenon. At a subsequent stage, the ends of the fibre commonly cease to be fixed, in consequence of the intermediate portions, by their contraction, receiving some of the pressure of the glass. The contractions, therefore, increasing in number and extent, gradually engage the whole substance of the fibre, which then is reduced to at least one third of its original length." *

To this experiment, which I have never been able successfully to repeat, some exceptions may be taken. Thus it is known that water has a powerful and remarkable effect in exciting muscular fibre which still retains its irritability to contraction, and the nodulated aspect of the fibre mentioned may have been due to the fact, that the fibre was not entirely immersed in water (the piece of mica being merely moistened), but only touched by that fluid at certain intervals, which most probably corresponded with the bulgings of the fibre referred to. This explanation is supported by the effect of water on recent muscular fibre, entirely immersed in that liquid. Thus, on the moment of immersion, the fibres contract greatly in length, increase in a corresponding proportion in bulk, become irregularly bulged and nodulated: the transverse lines on the fibres disappear, the longitudinal lines at the same time becoming more strongly marked than usual. (See Plate XLII. *fig.* 3.) These several effects are due to the extraordinary, unequal, and doubtless, also, abnormal contraction induced by the stimulus of water. Presuming, therefore, that in the experiment referred to, the phenomena occur in the order described, yet it would not be safe to adopt the conclusion from this, that they represent the several stages of the normal contraction of a muscular fibre. Again, it might be argued, that the nodular condition described as belonging to a muscle in a state of active contraction would be most unfavourable for the full exercise of the power of contraction, seeing that the nodules of one fibre would necessarily interfere with those of the contiguous fibres, and thus impede its own as well as their contraction.

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* Physiological Anatomy, pp. 180, 181.

For the above reasons, therefore, I would place but little reliance upon the experiment quoted, and prefer to adopt an explanation more simple in its character, and yet entirely sufficient to explain the condition of a muscle during its state of most active yet entirely normal contraction.

I conceive that no distinct line of demarcation exists whereby active and passive muscular contraction can be discriminated: the two are but different degrees of the same power, and manifest themselves by phenomena which differ not in kind, but simply in extent.

If a muscle of the leg of a frog be isolated from its fellows, or if the tongue of the same animal be extended and pinned to the margins of an aperture made in a piece of cork, the only change which can be observed to take place in the muscular fibre, when stimulated to contraction, consists in an approximation of its striæ, neither waves nor nodules manifesting themselves in its course.

Again; immersion of muscular fibre, which has almost lost its contractile power in water, will be followed by an approximation of the striæ, and a proportionate increase in the diameter of the filament.

Now, the approximation of the striæ is the only visible sign which I have ever been able to detect in natural muscular contraction; and it is amply sufficient to account for the shortening and increase in diameter which a muscle undergoes during its state of most active contraction.

The distance between the striæ in a fibre placed somewhat on the stretch, as are all muscular fibres in their natural state, and in that which is in a state of contraction, varies greatly, and is very evident, the striæ in the contracted fibre being often one third or even one half closer together than they are in the fibre in its ordinary state of tension. The approximation of the striæ to the extent just mentioned, presuming the entire length of the fibres to be in a contracted condition, would reduce the length of the muscle in the same proportion, viz. to the extent of a third or even one half.

Muscular contraction, then, I would define to be a simple shortening of the fibres of a muscle, accompanied by an increase in their breadth; this shortening in the striped muscular fibre being evinced by an approximation of the transverse striæ as well as by an increase in its diameter, while in the unstriped fibre it is manifested solely by an increase in the thickness of the fibrillæ. (Plate XLII. *fig.* 3. *a*, *b*.)

Whether, in muscular contraction, the whole length of the fibres of a muscle is engaged, or part only of their length, or whether, during the continuance of the contraction of a muscle, its fibres remain in a state of quiescence; or whether they undergo an alternate contraction and relaxation in obedience to the interrupted stimulus derived through the medium of the nerves, it is not easy to determine with certainty; nevertheless, it is most probable that where the contraction is very intense and long sustained, such an alternation of condition does exist.

The stiffening of the body, which occurs after death, known by the terms "rigor mortis," "cadaveric rigidity," is due to muscular contraction. This rigidity usually comes on a few hours after death; and after continuing for a variable time, not exceeding six or seven days, again disappears. There is much variety, however, in the exact periods of the advent and departure of the rigidity: it has been observed to come on latest, attain its greatest intensity, and to last longest in the bodies of robust persons, who have either died of short and acute diseases, or who have suffered a violent death. On the contrary, it has been remarked to set in soonest and to disappear earliest in persons of feeble constitution, and those who have died of a lingering and exhausting malady.

The immediate cause of cadaveric rigidity has never yet been satisfactorily explained. Some have supposed that it depends upon the coagulation of the blood in the capillaries — an hypothesis scarcely tenable: others, with more reason, conceive that it proceeds from the solidification of the fibrin of which muscle is chiefly constituted — that it is in fact a phenomenon precisely analogous to the coagulation of the fibrin of the blood.

An explanation differing from both of the former has suggested itself to my mind. I conceive that muscular contraction may possibly be brought about by the stimulus of the thinner and more watery parts of the blood, &c. acting on the still irritable muscular fibre, and which are known to escape from their containing vessels very shortly after the extinction of life. Of this passage of fluid through the walls of its receptacle we have a familiar instance in the case of the gall-bladder and its contents.

Two other points require to be briefly alluded to in relation to the subject of muscular contraction: the first is the *muscular sound* heard on applying the ear to a muscle in action, and which has been likened by Dr. Wollaston * to the distant rumbling of carriage wheels: the second relates to the fact made known by MM. Bequerel and Breschet, that *a muscle during contraction experiences an augmentation of temperature.*

DEVELOPMENT OF MUSCLE.

The muscular tissue, like the majority of those which have hitherto been described, takes its origin in cells.

The term fibre is applicable only to the striped form of muscle in which a number of fibrillæ are included in an investing sheath common to them: these striped fibrillæ of the striped fibre of voluntary muscles, are analogous to the unstriped fibrillæ of the involuntary muscles.

The process of the development of muscle may be divided into three stages: —

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* Phil. Trans. 1811.

In the first, isolated cells, arranged in linear series, unite to form the unstriped fibrilla, the nuclei remaining.

This stage appertains to all unstriped muscular fibre.

In the second, the transverse striæ or markings appear upon the fibrillæ, the nuclei still remaining.

This stage is permanently exemplified in the muscles of the heart, temporally in the voluntary muscles of the fœtus, and probably also in some few other muscles.

In the third period, the fibrillæ become very slender, the transverse markings more defined, and the nuclei altogether disappear.

This condition is represented in all the fully developed striped muscles of animal life.

But the striped voluntary muscular fibre, even of the adult, constantly exhibits and is constantly passing through the three stages just described; a fact not generally known. It has been ascertained, indeed, since the time of Valentin, that the striped muscular fibre of the fœtus originates in cells, and also that cell nuclei are contained in each fibre of the adult; but it has not been perceived that the fibrillæ also proceed from cells, and that the stage of muscular development, that of unstriped muscular fibre likewise exists in the voluntary muscles of both the fœtus and the adult.

It has been supposed, as we have already seen, that the nuclei which are met with in the striped muscular fibre are scattered throughout its entire thickness: this has been shown to be erroneous, and also that the nuclei are situated only on the exterior of each fibre.

Now in every adult striped muscular fibre, we find the nuclei under the following circumstances: some few of them are in a free state, others more numerous are contained in fibrillæ, both striped and unstriped: of these fibrillæ, the majority are on the inside of the sarcolemma; but some of them are also on its exterior, adhering to its surface, and constituting a considerable part of its substance: lastly, internal to these nucleated fibrillæ other fibrillæ, which form the chief bulk of each fibre exist destitute of nuclei.

With a good defining object-glass many of these unstriped fibres may be traced for a considerable distance along the fibre, and may be observed to contain as many as twenty nuclei.

From these several facts it would thus appear, that striped and unstriped muscular fibre, do not represent distinct types of structure, but that each is to be regarded as a different stage in the development of the same. The unstriped muscular fibrilla passes through but one stage of growth, and then its development becomes permanently arrested: the fibrillæ of the heart, &c. attain a higher degree of development, the nucleated fibres becoming marked with transverse striæ; after which their growth permanently ceases; lastly, the striped fibrillæ of the voluntary muscles reach the third and last period in the development of the muscular tissue, having their nuclei obliterated, and becoming exceedingly slender.

It would appear also that new fibrillæ are constantly being developed, even in the adult muscular fibre.

But certain appearances may be observed which render it extremely probable that not merely new fibrillæ are constantly being developed, but also that new fibres are continually being formed.

Thus, it is a common thing to meet with unstriped and even striped fibrillæ, which are slightly adherent to the external surface of the sarcolemma; again, small muscular fibres attached to the larger fibres, and consisting of but very few fibrillæ, may constantly be observed. (Plate XLII. *fig.* 4.)

In the uterus we have a very remarkable example of a periodic development and subsequent absorption of unstriped muscular fibrillæ.

The last point to which reference need be made is, to the doubt expressed as to "whether the identical corpuscles originally present" (in the fibre) "remain through life, or whether successive crops advance and decay during the progress of growth and nutrition."* This matter is no longer doubtful: the particulars observed in relation to the development of muscular fibre enable us to give a solution of the difficulty. Thus, there is no question but that successive crops of corpuscles or nuclei are continually being formed in both the striped and the unstriped muscles, and that those in the former are permanent, whilst in the latter they are only transitory.

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* Loc. cit. pp. 182, 183.

It will be readily perceived that the above detailed views of the structure and development of the muscular fibre differ, in very many important particulars from those generally entertained. According to the views of most physiologists, the unstriped muscular fibre is the analogue of the striped fibre; while, according to those of the author, the striped fibrilla is the analogue of the unstriped fibrilla, or "fibre" of most writers. Dr. Carpenter, in the third edition of the "Principles of Human Physiology," thus clearly gives expression to the notion that the striped and unstriped muscular fibres are the analogues of each other. "From the preceding history, it appears that there is no difference at an early stage of development between the striated and the non-striated forms of muscular fibre. Both are simple tubes, containing a granular matter, in which no definite arrangement can be traced, and presenting enlargements occasioned by the presence of the nuclei. But whilst the striated fibre goes on in its development, until the fibrillæ, with their alternation of light and dark spaces are fully produced, the non-striated retains throughout life its original embryonic character." The description just quoted, in its application to the *fibrillæ* of the striped and unstriped muscle, would be most true, but in its comparison of the unstriped fibrillæ with the entire striped fibre, it is completely at fault.

There is considerable discrepancy between the views entertained by Bowman and Valentin, and those expressed in this work, in relation to the development of muscle, as will be evident from the statement of them by the former gentleman. "The researches of Valentin and Schwann have shown that a muscle consists, in the earliest stage, of a mass of nucleated cells, which first arrange themselves in a linear series, with more or less regularity, and then unite to constitute the elementary fibres. As this process of the union of the cells is going forward, a deposit of contractile material gradually takes place within them, commencing on the inner surface, and advancing towards the centre, till the whole is solidified. The deposition occurs in granules, which, as they come into view, are seen to be disposed in the utmost order, according to the two directions already specified. These granules or sarcous elements being of the same size as in the perfect muscle, the transverse stripes resulting from their opposition are of the same width as in the adult; but as they are very few in number, the fibres which they compose are of corresponding tenuity. From the very first moment of their formation these granules are parts of a mass, and not independent of one another; for, as soon as solid matter is deposited in the cells, faint indications of a regular arrangement in granules are usually to be met with. It is common for the longitudinal lines to become well defined before the transverse ones: when both are become strongly marked, as is always the case at birth, the nuclei of the cells, which were before visible, disappear from view, being shrouded by the dark shadows caused by the multitudinous refractions of the light transmitted through the mass of granules; but they can still be shown to exist in the perfect fibre, in all animals, and at all periods of life, by immersion in a weak acid; which, while it swells the fibrous material of the granules, and obliterates their intervening lines, has no action on the nuclei."

According to the views entertained by the author, a striated muscular fibre, in the earliest period of its development, consists of cells arranged in linear series: these unite together, giving origin to the fibrilla and not the fibre, and that each fibrilla of a fibre is, in like manner, developed from cells.

Dr. Sharpey, in the fifth edition of Quain's Anatomy, makes the remark, in treating of the subject of the development of muscle, "But much still remains to be explained by future investigation." The truth of this remark it is conceived is, in some degree, exemplified in the foregoing article on muscular fibre.

Art. XIX. NERVES.

The nervous system has been divided into two orders or lesser systems; the cerebro-spinal, which includes the brain and spinal cord, together with the nerves which proceed therefrom, and the sympathetic systems. The former, which admits of still further leading divisions, presides over animal life, its nerves administering to sensation, and being distributed to the principal organs of locomotion, the muscles, as well as to those of the senses; the latter is connected with the functions of organic life, and supplies principally the viscera and glands with nerves.

Corresponding with the presumed functional differences of the two systems, there are also certain structural differences, the nature of which will shortly be described.

STRUCTURE OF NERVES.

Cerebro-spinal system. — The nervous matter constituting the cerebro-spinal system consists of two very distinct substances, a grey, cineritious, cellular, or secreting structure, and a white, conducting, or tubular structure.

Secreting or Cellular Structure. — The very numerous situations in which the grey matter of the brain and spinal cord is encountered need not here be described at any length: it will be sufficient to observe, that in the cerebrum it occupies principally an external situation, a layer of it of about the one-eighth of an inch in thickness, extending over the entire surface of its convolutions; but that it is also found in lesser quantities in several localities in the interior of the cerebrum, as in the optic thalami, corpora striata, tuber cinerium, crura cerebri, &c.; that on the other hand, in the cerebellum, pons Varollii, medulla oblongata, and spinal cord it is deep seated, forming the central portion of these organs.

The secreting substance or grey matter of the brain is made up of a granular base, in which are contained numerous nucleated cells of different sizes and forms. In the grey matter of the convolutions of the brain the granular base is very abundant, the cells small and round, and in less proportion than the base itself: in the tuber cinereum, in the cerebellum, and in the grey matter of the cord, the small granular cells are extremely abundant, and the granular base is diminished in quantity. (See Plate XLV. *figs.* 2, 3.)

Now the granular base and the small granular cells constitute the principle portion of the substance of the grey matter wherever encountered: in certain localities, however, cells of different forms and of considerable magnitude are met with: these cells have been termed ganglion cells.

Ganglion Cells. — Ganglion cells are encountered in different portions of the cerebro-spinal system, as in the locus niger of the crura cerebri, in the grey matter of the arbor vitæ, and corpus dentatum of the cerebellum; in the medulla oblongata; in the spinal cord for its entire length, and according to Valentin and Purkinje, in all the extent of the cerebral hemispheres, especially in the posterior lobes, and in the grey lamina of the spiral fold of the cornu Ammonis.

These cells vary greatly both in size and shape; many of them attain a very considerable diameter, and they are, almost without exception, all provided with caudate prolongations, which are frequently branched. (See Plate XLIV. *fig.* 4.)

The ganglioniform cells of the locus niger are for the most part small, and irregularly stelliform in shape: those of the grey matter of the cerebellum are pyriform, the spinous and often branched processes, usually two or three in number, proceeding from their narrow extremities: many of the cells of the medulla oblongata are triangular, the spines arising from the angles, and being much produced, those of the spinal cord are usually very large, irregular in form, and are furnished with numerous prolongations.

These cells are highly and uniformly granular: they frequently contain pigmentary matter, and enclose a nucleus, which again is provided with its nucleolus, and both of which are remarkable for their exceeding brilliancy.

Ganglion cells are doubtless connected with the secretion of the nervous element or fluid: the use of the prolongations with which they are furnished, and the precise relation of these with the adjacent structures, the smaller secreting cells and the nerve tubules, is not yet well ascertained: it has been conjectured, however, that the caudiform processes are directly continuous with the tubules; a view which is certainly incorrect.

Mixed up with the ganglion cells wherever met with, but especially with those occurring in the grey matter of the cerebellum and spinal cord, a considerable number of branched and nucleated fibres may be seen similar in appearance and structure to those of unstriped muscle, and more particularly resembling the gelatinous filaments of the sympathethic system, from which they in all probability really proceed.

There is a second description of ganglion cell, not contained in either the brain or spinal cord, but found in the various ganglia, as the Casserian, Ottic, Opthalmic, Spinal, &c., formed in connection with the nerves of the cerebro-spinal and sympathethic systems, and which may be here described.

These cells resemble the ganglion corpuscles already noticed in their general structure, but differ from them in form, being more or less round in shape, and destitute of the branched processes belonging to the latter. (See Plate XLV. *fig.* 4.)

The mode of multiplication of ganglion cells is not well understood: it is possible that the numerous granules contained in each are the germs of the future cells. Adhering to the surface of many of the larger ganglion cells of the second form, a number of nucleated particles or lesser cells may frequently be observed, forming a kind of capsule around them, which, however, is entirely external to the proper membrane of the cells. (See Plate XLV. *fig.* 4.)

Tubular Structure. — The white fibrous substance of the brain, spinal cord, the nerves of motion and of special sensation, is composed of unbranched tubules, the diameter of which is subject to considerable variation. The tubules of the cerebrum are exceedingly slender, as are also those of the nerves of special sense: those of the cerebellum, spinal cord, posterior root of spinal nerves, and of the sympathetic system are of somewhat larger calibre, while those of the motor nerves are of still larger size, and of firmer texture. See the figures.

The tubules of the white substance of the cerebrum are especially prone to become dilated at intervals, or varicose. (See Plate XLIV. *fig.* 7.) This condition was formerly supposed to be natural, and it was presumed, that by this character the nerves of special sense could be discriminated from those of motion: there is little doubt, however, but that this varicose condition of the fibres is abnormal, and that it is produced by the pressure and disturbance to which they are subject during examination. The tubules of the cerebellum are subject to a like change, although in a less degree; those of the nerves of motion are but little prone to the alteration, these becoming, when much disturbed, broken into fragments, many of which assume a globular form, and all of which are greatly corrugated. (See Plate XLIV. *fig.* 1.)

The nerve tubules contain a fluid matter, and it is the collection of this fluid in certain parts of each tubule, the result of pressure, which occasions the distension of the membranous wall of the tubes, and which gives rise to the varicose condition described. Such, is at least, the most probable explanation of the exact nature of this condition.

The tubules of the cerebrum, cerebellum, spinal cord, and motor nerves, &c., present an average diameter: nevertheless, much difference may be detected in the size of the tubules taken from the same portion of the nervous system:

those of the spinal cord agree in their average size with those of the cerebellum.

The tubes of the cerebrum, of the nerves of special sense, and of the cerebellum are so small, that it is impossible to ascertain with certainty the amount of organisation which really belongs to them: this, however, is not the case with those of the motor nerves, which are so much larger. (See Plate XLIV. *fig.* 1.)

Each tube of a motor nerve consists of an investing sheath or *neurolemma*, an inner elastic and but little consistent matter,' the "white substance of Schwann," which forms a pseudo membrane, and which includes the third constituent of the nerve tube, a soft and semi-fluid matter, which, however, would appear in some cases to become solid, and to exhibit a fibrous fracture: this matter has been termed the "axis cylinder."

It is a matter of some difficulty to display the investing sheath, or neurolemma, around the fibres in their fresh and unaltered state: it may, however, be easily detected, and its structure recognised in a portion of motor nerve which has been immersed for some hours in spirit: it will then be seen that it is made up of nucleated fibres, the nuclei in the sheath of fœtal nerve tubes being of considerable size, and presenting a smooth aspect. (See Plate XLIV. *fig.* 2.)

Todd and Bowman describe the outer membrane of the nerve tube, and to which alone the word neurolemma should be applied, "as an homogenous and probably elastic tissue of extreme delicacy, analogous to the sarcolemma of striped muscle, and, according to our observation, not presenting any such distinct longitudinal or oblique fibres in its composition as have been described by some writers." It will be observed that this description does not accord with that given by the author.

The white substance of Schwann, on the contrary, is best seen in the motor nerve tubes, which are perfectly recent, and which have been but little disturbed: its thickness is indicated by a double line which runs along each side of the tube: it does not present any trace of organization: it is very elastic, and its contraction gives rise to the corrugated appearance presented by the tubes of motor nerves which have been disturbed and broken. (Plate XLIV. *fig.* 1.)

The existence of the third constituent of the nerve tube, the "axis cylinder" of Rosenthal and Purkinje, is best determined by the immersion of the fibres in either ether or acetic acid, which breaks it up into granules and vesicles. (Plate XLIV. *fig.* 3.)

In albumen the nerve tubes and nervous tissue in general undergo but little alteration, and it is therefore in this fluid that its examination is best conducted.

But the tubes of the white fibrous material of the cerebrum, cerebellum, and spinal marrow just described, form one element only of its structure; another is invariably present, forming indeed the greater portion of its substance; and it is somewhat strange that it should have been overlooked by observers: this element consists of globules of every possible size, which, when free from pressure and undisturbed, are perfectly spherical but which are put out of shape by the slightest compression or disturbance. It is not easy to determine whether these globules are true cells or not: they present the greatest possible variety of size: they have the colour and consistence of oil; but nevertheless appear to be hollow, and frequently present a spot which bears much resemblance to a nucleus. (See Plate XLIV. *fig.* 6.)

It now only remains to be observed, that the nerves of special sense, as the optic, olfactory and auditory, present a structure precisely analogous to that of the white substance of the cerebrum.

SYMPATHETIC SYSTEM. The nerves entering into the formation of the sympathetic or organic system differ both in appearance and structure from those derived from the cerebro-spinal system: thus the great sympathetic cord itself, as well as the organic nerves connected with it, present a reddish grey colour, are soft and gelatinous, and do not readily admit of division in the longitudinal direction, although they are easily torn across by any extending force: these differences of colour and of consistence are dependent upon a difference of structure. The great sympathetic cord itself, and the organic nerves connected with it, are composed of two distinct descriptions of fibre; first, of the ordinary tubular fibre, which, however, is of small diameter, and therefore readily becomes varicose, and second, of nucleated filaments, in every appreciable respect resembling those of unstriped muscular fibre. Henle has called these fibres "*gelatinous nerve fibres.*"

The relative proportions existing between these two kinds of fibre differs in different nerves: thus in some cases the gelatinous fibres are by far the most numerous; in others, the tubular fibres preponderate. The gelatinons or grey filaments are best seen in what are called the roots of the sympathetic; that is to say, in the branches which accompanying the carotid artery, proceed from the superior cervical ganglion to the fifth and sixth pair of cerebral nerves, and in those which descend from the same ganglion and follow the course of the carotid. In these the proportion of tubular fibres is but small, as one to six; and they are also isolated from each other, each being surrounded with a number of gelatinous fibres. This disposition of the nucleated fibres has led Valentin to consider that they form a sheath around the tubular fibres, each grey nerve, according to that observer, being composed of a number of fascicles or bundles. Henle, however, objects to this view, considering that the fibres are too large for a sheath, and remarking that the grey nerves do not separate into such bundles, but divide much more readily in such a way as that the tubular fibre is found at the border of the bundle. Henle, therefore, considers it to be more natural to regard the grey nerves as forming solid threads, composed of nucleated filaments between which the tubular fibres run.

The tubular fibres are more numerous than in the roots of the great sympathetic in the majority of the visceral nerves, in the branches which proceed from the cardiac and hypogastric plexuses, &c.; in these the tubular fibres may be seen enclosed within the grey filaments, forming many bundles. Their number becomes still more considerable in the great sympathetic cord itself, and the splanchnic nerves; the cardiac nerves are almost entirely formed of tubular fibres. In all these nerves the tubular fibres are observed to be of smaller diameter than they are in those which are distributed to the voluntary muscles.

In consequence of the great difference which exists between the structure of the tubular nerve fibre and that of the gelatinous nerve fibre, it has been a matter of doubt with some observers whether the latter should be regarded as a true nerve fibre or not.

The following is a brief enumeration of the various anatomical and microscopical facts hitherto recorded both in favour of and opposed to the opinion of the nervous character of the gelatinous filaments just described.

The chief structural considerations which may be urged in favour of the opinion that the nucleated filaments associated with the various nerves of the sympathetic system are true nerve filaments are —

1st. The origin of the gelatinous filaments from the ganglia of the sympathetic, as first distinctly affirmed in the researches of Volkmann and Bidder.*

2nd. The tubular character of these filaments, as shown by T. Wharton Jones.†

3rd. The periphral distribution of the gelatinous filaments, as asserted by many observers, but particularly by Bidder, who even states that he succeeded in counting their number in the transparent septum of the auricles of the frog's heart.

4th. The peculiar structure of the ganglion cæcum, discovered by Mr. T. Wharton Jones, in connexion with one of the ciliary nerves of the dog.‡

5th. The variable yet fixed proportions of gelatinous and tubular fibres occurring in different nerves, as described especially by Henle.

6th. The occurrence, as stated by Todd and Bowman, of nucleated filaments very similar to the gelatinous fibres of the sympathetic "in parts where their nervous character is indubitable, as in the olfactory filaments, and the nerve in the axis of the Pacinian corpuscle exhibits very much the same appearance save that it is devoid of nuclei," *

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* Die Selbstandigkeit des Sympathisken Nervensystems durch Anatomische Untersuchungen nachgewiesen Von J. H. Bidder und A. W. Volkmann. Leipsig, 1842.

† Lancet, April 24th, 1847.

‡ Lancet, November 14th, 1846.

7th. The resemblance borne, according to the observations of Schwann †, between the tubular nerve fibre in the early stages of its development, in which it is described as being nucleated, and the adult gelatinous fibre.

8th. The origin of the gelatinous filaments from the cells themselves composing the ganglia of the sympathetic, as the observations of several observers tend to prove.

These various facts thus briefly referred to, could they all be fully depended upon, would, doubtless, make out not merely a strong, but even a convincing and unanswerable case in favour of the nervous character of the gelatinous filaments: unfortunately, however, those facts, which, if they could be relied upon, would be the most conclusive, are open to question: such, for instance, as the periphral distribution of the gelatinous filaments, their presumed origin from the ganglionic corpuscles, and the asserted resemblance between the tubular nerve fibre in an early stage of its development and the fully grown gelatinous filament; it will presently be shown, indeed, in the observations on the growth of the primitive nerve tubule that no such resemblance exists.

Subtracting then the points referred to in the 3rd, 7th, and 8th headings, no one conclusive fact remains of the position that the gelatinous fibres are really nervous.

Against the opinion that the gelatinous filaments are nervous, may be urged —

1st. The positive structural identity between the gelatinous nerve filament and the fibrilla of unstriped muscle, and the great improbability, as a consequence, that one and the same structure should have to perform two such distinct functions as must necessarily belong to a muscular fibre and a nerve tube.

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* Physiological Anatomy, part iii. p. 142.

† See Wagner's Physiology, translation by Willis.

2nd. The apparent structural unfitness of nucleated filaments to serve as a conducting medium of the nervous force.

3rd. The evidently tubular character of the nerve filaments in parts which, from their nature, we should expect would be pre-eminently supplied by the gelatinous filaments.

4th. The fact of the non-occurrence of gelatinous fibres, separate from the tubular, is strongly opposed to the idea of the independence of the former.

The above short summary will serve to give some idea of the state of the much canvassed question of the nervous or non-nervous character of the grey or gelatinous filaments of the sympathetic.

STRUCTURE OF GANGLIA.

The ganglia consist of the peculiar globules already described, of nerve tubules and of gelatinous filaments.

Each ganglion is enclosed in an investing tunic of fibrous tissue, a continuation of the common envelope of the nerves which enter and depart from it, and which sends down dissepiments which divide the contained globules into parcels, and thereby give the ganglion the general arrangement and character of a gland.

The gelatinous nerve filaments in the ganglion form a kind of inner capsule, and their arrangement is thus described by Henle: "Besides the nervous fibres properly so called of the soft nerves, one meets with also, in the ganglions of the great sympathetic gelatinous fibres which have special relations with the ganglionic globules. The fibres of a bundle expand in the form of a funnel, in order to embrace a globule or a series of globules, and unite together afterwards afresh, to separate again a second time. In this way we often come to draw out of a ganglion entire threads of gelatinous fibres, which are dilated, in the manner of a chain of pearls, and enclosing the globules in their dilatations."

The proper tubular fibres enter the divisions of the ganglion in bundles, subsequently separate from each other, and ramify amongst the ganglion globules in a waved and serpentine manner.

The arrangement of the ganglion globules and nerve tubules just indicated, tends to show that these are really the only essential elements of a ganglion.

The ganglia are supplied with blood-vessels.

It will be apparent from the above description that the ganglia have all the structural characteristics of glands, and therefore there can be little question but that they are really glandular organs, and that the tubular fibres which pass through them carry away the fluid, which is destined to exercise its influence on the parts and organs to which the nerves are themselves distributed.

The question as to the origin of either the tubular fibre or the gelatinous filament from the ganglionary corpuscles, is still an undecided one, the weight of evidence being opposed to the idea, that either order of fibres has any origin from these corpuscles.

ORIGIN AND TERMINATION OF NERVES.

Origin. But little that is certain is known respecting the exact mode of origin of the numerous tubules composing the nerves, and of the precise relation of these with the cellular or secreting element of the ganglionic centres. The observations of Dr. Lonsdale *, however, render it highly probable that the greater portion at least of the nerve tubes have a looped origin in the brain and spinal cord: that gentleman having made out the interesting fact, that in two fœtuses, in the one of which both the brain and spinal cord were deficient, and in the other the brain only, the extremities of the nerves, which extended into the cavities of the spinal column and cranium were made up of looped nerve tubes imbedded in an imperfectly developed granular and cellular matter, apparently of a ganglionic character. Now, from what is known respecting the laws of development, it would appear to be a perfectly justifiable and natural inference, that the nerve tubes, when fully developed, have a similar mode of origin.

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* Edinburgh Medical and Surgical Journal, No. cxvii.

According to some observers, certain nerve tubes are connected with and take their origin from the prolongations with which the caudate variety of ganglionary cells are provided: this view, however, is confidently denied by many other investigators, and the point is one which is still involved in considerable uncertainty: for myself I would observe, that I have never succeeded in making a single observation favourable to such a conclusion. Notwithstanding, however, the doubts which are now entertained respecting the modes of origin of nerve tubes, the question is assuredly one which, at some future day, will be satisfactorily determined by direct observation.

It is also still uncertain, whether nerve tubules originate in the ganglia not included in the brain, as in those connected with the encephalic nerves, and those of the sympathetic system.

When speaking in the preceding remarks of the origin of nerves, that extremity of them is implied which is in connexion with the brain and spinal cord: it is questionable, however, in the case of the nerves of special sense, whether it would not be more proper to consider their periphral rather than their central extremities as their true origins; a view supported by the consideration that the sensations arise in, and proceed from, the organs of the senses inwards towards the brain, the great centre of nervous structure and force, as well as by the fact, that the periphral extremities of these nerves are generally, if not invariably, connected with ganglionic cells; such an association of the two elements is known to exist in the eye, in the ear, in the nose, and probably exists also in the papillæ of the tongue and skin.

Termination. It was not known until within the last four or five years that nerves had any real termination: it was up to that time generally considered that the nerve tubes invariably ended in the same manner as it is now supposed that they originate, viz. in loops, and there can be little question but that such a mode of termination, though not universal, is at least very frequent: thus, the arrangement of the primitive nerve fibres in loops has been described by Valentin, in the pulps of the teeth; by Müller, in the membrana nictitans, and in the mucous membrane of the throat of the frog; in the papillæ of the skin and tongue, by Todd and Bowman. The loops are formed by one or more of the nerve tubes, separating themselves from the bundle of tubes composing every nerve of any magnitude, and afterwards either passing into and mingling with those of a neighbouring nerve, or else returning back to that from which originally it started.

It is now, however, very certain, that some at least of the nerve tubes have a real termination: this is indisputably the case with the single filaments which enter the Pacinian bodies; it has also been shown to occur with many of the primitive tubes distributed to muscles.

PACINIAN BODIES.*

The Pacinian bodies are found in considerable numbers attached to the cutaneous nerves of the hands and feet, especially to those of the extremities of the fingers and toes; they are also met with, though more sparingly, on other spinal nerves, on the plexuses of the sympathetic, but never on the nerves of motion, and in the mesentary; in that of the human subject, however, they are only with great difficulty to be discovered owing to its thickness and the quantity of fat usually contained in it: in the mesentary of the smaller mammalia, as the cat, rabbit, &c. and more particularly when these are in a lean state, they may be readily discerned with the naked eye, and the entire of their structure followed out without even the employment of a reagent: it is therefore in these animals that they are studied to most advantage.

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* The discovery of these remarkable bodies constitutes one of the happiest and most beautiful results of the application of the microscope to minute anatomy. Pacini first noticed them in 1830, subsequently in 1835; but it was not until 1840 that he gave an account of them. (Nuovi organi scoperti nel Corpo umano dal Dott Filippo Pacini, Pistoja). A. G. Andral, Camus, and Lacroix, announced their existence at a *Concours* at Paris in 1833, but do not appear to have recognized their real character.

The Pacinian bodies vary greatly in size, but are usually as large as the head of a pin of ordinary magnitude; they are of an oval or pyriform shape, are perfectly translucent, attached to the nerve filaments by short pedicels, and occur either singly or sometimes in pairs. (See Plate XLVI. *fig.* 1.

So large are these peculiar bodies that the whole of their structure may be followed out with object glasses of an inch and half-inch foci; when examined with these magnifying powers each Pacinian body is observed to consist of numerous concentric lamellæ or capsules disposed with much regularity; these lamellæ are formed of white fibrous tissue, contain numerous nuclei in their substance, and are separated from each other by distinct intervals which contain fluid; the spaces intervening between the plates do not communicate and diminish gradually but regularly from without inwards, so that the central lamellæ are almost in contact with each other, from which cause they present a darker aspect than do those having appreciable spaces dividing them the one from the other: these capsules have been distinguished from the rest by the term the "*inner system of capsules.*" It is this regular disposition of the lamellæ together with their gradual approximation which imparts so beautiful an appearance to these strangely constituted organs. The capsules, however, are not continued to the very centre of the Pacinian body; but in that situation a cavity, having a somewhat elliptical form and filled with fluid exists. This cavity opens externally by means of a canal which pierces the whole of the lamellæ and the sides of which canal are formed by the union of those lamellæ: into this canal a single nerve tube passes, enters the central cavity just described, which it traverses from end to end in a straight line, terminating in a slightly enlarged extremity, which is described as being attached to the inner wall of the distal end of the central chamber; the nerve tube, immediately on its entrance into this chamber, loses its double and defined border, in consequence, it is presumed, of the absence of the white substance of Schwann. (Plate XLVI. *figs.* 2, 3.)

Such is a brief and general description of the Pacinian body; one or two other points of a less evident character still remain to be noticed. It has been stated that the capsules contain elongated nuclei in their parietes, that they are formed of fibrous tissue, and that the spaces between them have no communication with each other: if the outer and larger capsules be carefully examined it will frequently be observed that they present a double edge separated by a faint interval, and conveying the impression that each capsule is made up of two distinct membranes: it is in this interval that the nuclei are lodged: that the inter-capsular spaces do not communicate with each other is proved by the fact that when the outer capsules are pierced through, the fluid escapes only from the spaces which have been opened into; if the whole of the capsules have been divided the entire corpuscle immediately collapses. (It is a curious fact that a Pacinian body allowed to dry up does not again absorb fluid and expand to its natural size.) It has also been observed that the capsules are united to each other at the proximate extremity of the Pacinian body along the sides of the canal already described: according to Pacini they are also bound together at the distal end by a band of fibrous tissue, which he calls the "*intercapsular ligament:*" the existence of this ligament has been denied by Henle and Kœlliker.* Todd and Bowman do not deny its existence, but state that they have seldom seen it reach the surface of the corpuscle.†

Pacinian bodies not unfrequently present varieties of form and structure: it is possible that many of these admit of explanation on the supposition that in some instances they are multiplied by self-division: thus sometimes the distal end of the central chamber is bifid, the nerve tube being also divided; in others a single corpuscle will be found to contain two distinct chambers and nerve tubes, each being surrounded by a certain number of capsules, but which again are themselves included in a number of other capsules which embrace both the sets of inner membranes: again, in other instances, two Pacinian corpuscles, entirely formed, but yet not altogether separated from each other, being connected by a few of the capsules will be situated upon a single primitive nerve tube: a fourth peculiarity, which may be noticed more frequently than any of the others, is the curling back of the extremity of the central chamber, the innermost capsules describing the same curvature. (See Plate XLVI. *figs.* 4, 5.)

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* Ueber die Pacinischen Körperchen an den Nerven des Menschen und der Säugethiere, Zurich, 1844.

† Physiological Anatomy, vol. i. p. 397.

DEVELOPMENT AND REGENERATION OF NERVOUS TISSUE.

Development of nerve fibres.—The following is the account given by Schwann of the development of the nervous cords as rendered by Willis in his translation of Wagner's Physiology, the references to the figures only being omitted. "The nerves appear to be formed after the same manner as the muscles, viz. by the fusion of a number of primary cells arranged in rows into a secondary cell. The primary nervous cell, however, has not yet been seen with perfect precision, by reason of the difficulty of distinguishing nervous cells whilst yet in their primary state from the indifferent cells out of which entire organs are evolved. When first a nerve can be distinguished as such, it presents itself as a pale cord with a longitudinal fibrillation, and in this cord a multitude of nuclei are apparent. It is easy to detach individual filaments from a cord of this kind, ... in the interior of which many nuclei are included, similar to those of the primitive muscular fasciculus, but at a greater distance from one another. The filaments are pale, granulated, and (as appears by their farther development) hollow. At this period, as in muscle, a secondary deposit takes place upon the inner aspect of the cell membrane of the secondary nervous cell. This secondary deposit is a fatty white-coloured substance, and it is through this that the nerve acquires its opacity. With the advance of the secondary deposit, the fibrils become so thick, that the double outline of their parietes comes into view, and they acquire a tubular appearance. On the occurrence of this secondary deposit the nuclei of the cells are generally absorbed; yet a few may still be found to remain for some time longer, when they are observed lying outwardly between the deposited substance and the cell membrane, as in the muscles. The remaining cavity appears to be filled by a pretty consistent substance, the band of Remak, and discovered by him. In the adult, a nerve, consequently, consists, 1st, of an outer pale thin cell membrane—the membrane of the original constituent cells, which becomes visible when the white substance is destroyed by degrees; 2nd, of a white fatty substance deposited on the inner aspect of the cell membrane, and of greater or less thickness; 3d, of a substance, which is frequently firm or consistent, included within the cells, *the band* of Remak."

The author's observations lead him to entertain views of the development of the primitive nerve tube essentially distinct from those expressed by Schwann in the account quoted above: according to these observations, the outer covering of the nerve tube does not consist of a structureless membrane, as is supposed by Schwann, as well as most other observers, but is constituted of a nucleated form of fibrous tissue. (See Plate XLIV. *fig.* 2.) Now, the nuclei observed by Schwann the author believes to be concerned in the development of the fibres, of which the proper membrane of each primitive nerve tube is wholly constituted, and that they do not by their growth give origin to a transparent tubular membrane.

In the nerve tubes of both young and adult animals, smooth bodies of an oval form and large size, their diameter exceeding that of the tube itself, may always be observed; the nature of these, and the part taken by them in the structure and development of the nerve tube, I have not been able to determine.

Development of Glandular Nerve or Ganglionary Cells.—The nervous matter composing the two or three systems into which, in the present day, it is divided, presents all the essential and distinctive characters of a true gland, so that its description would have been more correctly given under the general heading of "Glands."

The nerve or ganglionary cells present essentially the same structure as all other glandular cells, and are doubtless continually passing through the same phases of development and destruction during the progress of nutrition and secretion.

The secreting or glandular cells in the brain and spinal marrow, are for the most part aggregated into distinct masses, the term ganglia being equally applicable to these masses as it is to those existing in connexion with the nerves of the sympathetic system. Henle considers that the principal development of new cells takes place on the outer surface of the brain, which is the most vascular from its contiguity to the pia mater, and that the more mature cells are gradually conveyed inwards, coming thus into nearer connexion with the tubular or conducting fibres, the disintegration and removal of the older cells determining the movement of the cells from without inwards. This view, as applied to the grey matter of the convolutions of the brain is probably correct, and is to some extent confirmed by an observation which I made several months since, viz. that the cortical substance of the cerebellum consists of two distinct portions separated by a well-defined line, perceptible with a common magnifying glass: the outer portion is made up of a granular base, containing but few fully developed cells, while the inner portion consists almost entirely of completely formed cells. The distinct separation of the cortical or secreting matter of the cerebellum into two portions is very remarkable, and the purpose fulfilled by such an arrangement wholly obscure.

Regeneration of Nervous Matter.—The regeneration of the primitive nerve tube admits of proof, both by experiment and direct observation. The experimental proof consists in the simple division of nerves, and even in the removal of portions of them: the parts to which the nerve is distributed, of course at first, lose their sensory and motor endowments: these, however, after a variable time, are more or less perfectly recovered, thus completing the experimental proof. The direct proof is derived from the former: the recovery of the power of a nerve after the excision of a portion of it, argues strongly the fact of the regeneration of the nerve tubes; and this result, by a careful microscopic examination, can be positively demonstrated: the number of tubes in the renewed part of the nerve is stated, however, to be less than in the original portions; and this in part explains the reason of the restoration of the functions of a divided nerve being usually but imperfect. Other proofs of the regeneration of the nerve tubes may be gathered from the more or less complete restoration of various sensitive and motor parts of the body, as well as from the re-union of parts which have been entirely detached from the body, as the nose, the top of the finger, &c.

With respect to the regeneration of the glandular element of the nervous matter, but little definite or microscopic is known: from analogy, however, it may be inferred, that like other cellular structures, as the epidermis, epithelium, &c. it also is capable of a more or less complete reproduction.

RESEARCHES OF M. ROBIN.

The following is a translation of an abstract made by the author himself, M. C. Robin, of a paper communicated to the Royal Academy of Sciences at the Séance of June 21st, 1847, entitled "Researches on the Two Orders of Elementary Nerve Tubes and the Two Orders of Ganglionary Globules which correspond to them."

"The end of these researches is to show that the ganglions of the spinal nerves and of the great sympathetic do not give origin to elementary nerve tubes as many modern anatomists admit, as Hannover, Valentin, Remak, Bidder, and Volkmann, &c., &c.; but that all the nerve tubes arise exclusively from the spinal cord and the encephalon; consequently that one can only regard these ganglions as special little nervous centres performing, with respect to certain functions, the same office as does the cerebro-spinal centre for the other functions. These reflections naturally occur to the mind when one sees the cavity of the tubes or elementary nerve-fibres given off from the spinal cord, or from the encephalon, merge into the cavity of the ganglionary globules at one of their poles, and reappear at the opposite pole of the globule in the same manner that they entered.

" Setting out from a globule (cell) these nerve tubes proceed to lose themselves in the organs. Thus, those peculiar cells, the agglomeration of which constitutes the ganglions of nerves, are no other than organs which are interposed between the origin of the nerve tube and its termination at a determined point of its course, and, perhaps, there is more than one upon each tube: they interrupt it in its course to allow it once more to reappear; they change it, they modify its structure at a point to immediately restore it.

" The authors who have hitherto written upon the subject have not observed the entrance and exit of each elementary tube at the two opposite poles of each globule, but only the one or the other. It is this circumstance which has led them to consider each of these ganglionary globules as a little nervous centre of origin for each tube.

" There is yet another fact still more important than the first, which has not been pointed out by anatomists who have studied the structure of nerves.

" They have all described but one order of globules: there are, nevertheless, two which differ, the one from the other, in numerous characters, deduced from the consideration of size, form, contents, walls, &c. One of these orders of globules is always in connexion with the elementary nerve tubes of *animal life* or *the large tubes*, &c. The other is associated especially with the elementary tubes of *organic* or *sympathetic* life, or with the *small tubes*, &c. One never finds the large tubes communicating with the second order of globules, and reciprocally the small tubes are never in connexion with the poles of the globules of the first order.

"It follows from these facts, that one can no longer doubt the existence of the two orders (altogether extinct) of elementary nerve tubes named above, which, nevertheless, some authors have done recently. (Kölliker.)

"The two orders of globules, and of the corresponding tubes, exist in the posterior or sensitive roots of the nerves of the spinal cord, but the globules do not exist in the anterior or motor roots.

"They exist also in the ganglions of the encephalic nerves and of the great sympathetic; only in these last there is a much greater number of globules and of slender tubes than of globules and of large tubes (thirty or fifty to one), more or less according to the ganglions. In the spinal ganglions, on the contrary, there are about four or five globules and large tubes to one of the other kind.

"These facts tend to confirm the observations of anatomists who have pointed out the existence of the two orders of elementary tubes in the nerves of animal life and those of the great sympathetic, but with predominance of the large tubes in the first, and of the slender tubes in the second; notwithstanding which no one of them has pointed out the existence and the difference of the two orders of ganglionary globules.

"The absence of ganglionary globules on the *anterior* or *motor* roots of the spinal nerves anatomically distinguishes the elementary tubes of motor nerves of animal life from those of the sensitive nerves. But this decisive character can be remarked only in the short course of the roots of the spinal nerves before their union and the mixture of their tubes. If wishing to push still further the deductions to be drawn from the preceding facts, we demand of ourselves what functions should be attributed to the ganglionary globules, we should answer, that they are the modifiers of the action which takes place in the sensitive and in the organic nerves; but it is impossible to determine the nature of this modification.

"Since the ganglia of the sympathetic and of the cerebro spinal nerves enclose the same ganglionary globules and the same elementary tubes, but only in different proportions, we see that we cannot with Reil, Bichat, &c. acknowledge two nervous systems independent of each other. This opinion is founded on the communications of the great sympathetic with the spinal nerves; on the fact of nerves being furnished to the abdominal diaphragm of birds, exclusively by the great sympathetic (Sappey) on the partial and successive substitution of sympathetic nerves for spinal and encephalic in a great many vertebrata."

The above highly interesting observations of M. Robin need confirmation, and it is to be hoped that microscopic anatomists will direct their attention to the subject. In the many examinations which I have made of ganglia, I have never recognised the presence of two orders of ganglionary cells, nor have I ever perceived any attachment between the tubes and cells. I would remark, however, that I have made no examination of the ganglia and their constituent cells since the publication of the researches of M. Robin. There is one defect in the abstract of the author, of which we have given a somewhat literal translation, viz. that the distinctive characters of the two orders of ganglionary cells are not recited: it will be observed also that no mention is made of their occurrence in either the brain or spinal cord: from this I should judge that M. Robin was not acquainted with the delicate cells described by me in Part X. of this work, as existing in vast numbers in the white substance of the cerebum, cerebellum, spinal cord, and nerves of special sense wherever this occurs.

Art. XX. ORGANS OF RESPIRATION.

The organs of respiration seem to stand alone in the animal economy, and not to exhibit any strong structural relationship or affinity with any other organ or organs comprised in that economy. In their position and general form they bear some resemblance, in the mammalia at least, to glands: this resemblance, however, is more apparent than real, as becomes evident from the single consideration that the lungs are essentially destitute of the innumerable granular cells which constitute the chief bulk of true glands and form their distinctive and essential element. In a strictly natural arrangement the lungs would be more properly and correctly described in connexion with the circulatory apparatus; for essentially they are vascular organs, their only indispensable constituent being blood-vessels, so situated indeed as to admit of their being brought continually into contact either with air, or with water impregnated with air.

The great object aimed at in the formation of the lungs of mammalia is the construction of organs which shall occupy but little comparative space, and which shall yet present a greatly extended surface, throughout which the blood and air may be brought into close approximation. We shall now proceed to describe the manner in which this purpose is accomplished.

The tissue of the lungs of man and other mammalia may be divided into two systems of apparatus: the first comprises the circulatory or vascular apparatus, consisting of arteries and veins together with the plexuses formed by the union of the capillaries proceeding from both sets of vessels; the second comprises the respiratory or aeriferous system, which includes the bronchial tubes, the air cells and the ciliated epithelium. The intimate structure of the lungs will be best understood by an examination in the first place of the aeriferous apparatus.

AERIFEROUS APPARATUS.

The aeriferous apparatus of the lungs consists of bronchial tubes and air cells.

Bronchial Tubes. — The bronchial tubes are formed of cartilaginous rings united by elastic tissue: the rings, however, are imperfect, and are only present in the larger tubes, as those of the first, second, and third or fourth diameters: in the smaller tubes they are absent, these being composed entirely of a nucleated form of fibro-elastic tissue: they divide repeatedly in a dichotomous manner: it is not easy, however, to determine the number of divisions which each bronchial tube undergoes after its entrance into each lobule: it would appear, however, that the intra-lobular ramifications are less numerous than the interlobular branchings, the bulk of the lobule consisting chiefly of air cells.

The bronchial tubes are lined throughout by mucous membrane, which is invested by a stratum of cylinder ciliated epithelium. The smaller bronchial tubes are eminently elastic and contractile by virtue principally of the elastic tissue of which they are chiefly formed. This elasticity is still further increased in the case of the larger tubes by the presence of muscular fibrillæ of the unstriped kind.

Air cells. — The air cells are minute cavities of variable size, of an angular form, not dilated, which communicate freely with each other and the parieties of which are formed of a diaphanous, tough, highly elastic and delicately fibrous membrane, which contains and supports the capillary blood-vessels, and the interior of which is lined by a modified mucous membrane also invested with a layer of ciliated epithelium.

From this description, it becomes evident that the air cells contain the same structural elements as the smaller bronchial tubes themselves, and that they therefore differ from these solely in form and arrangement, possessing precisely the same general physical properties, being in the same manner highly elastic, a property mainly dependent upon the abundance of fibro-elastic tissue present in the lungs. (See Plates XLVII. and XLVIII.)

That the air cells do really communicate freely with each other (a fact which is now generally admitted, but which is yet denied by Dr. T. Williams*) may be satisfactorily determined in many ways. Thus it is by no means difficult to see the circular and ever patent openings of communication, both in injected and uninjected lungs; again, by injection with size, perfect casts of the cells may be obtained: these casts when a fragment of lung is torn up in water, readily escape, by which means the variety presented by the cells in form and magnitude may be accurately determined, as well as the shape and number of the openings of communication. (See Plate XLVIII. *fig.* 2.) Not unfrequently these casts are more or less coated with the epithelium lining the cells, as also represented in the figure just referred to.

So perfect and consistent are the models of the air cells procured in this way, that for some time I was led to entertain the idea that each little mass of size was really enclosed in a delicate and structureless membrane, which I conceived to be the true air cell lining, and I have scarcely yet been able to discard the notion altogether from my mind. If the lung be injected with tallow, we do not procure casts in the same number and perfection, because the tallow adheres closely to the sides of the air cells. Sometimes I have seen casts even without injection; but the occurrence of these is rare. It is, therefore, yet possible that I have not been deceived, and that a structureless membrane does really line the air cells, a modification of the mucous lining of the tubes, the "*basement membrane*" of Bowman.

It would appear from an examination of these casts, that the number of openings of communication varies from one to five; usually, however, but one, two, or three are present.

When looking attentively at these casts, covered with epithelial cells, and labouring under the impression that they were really distinct structures, I have sometimes perceived cells of glandular epithelium, one much larger than the rest, with a transparent border; and this I fancied was a fresh cell membrane in process of development.

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* Essay on the Structure and Functions of the Lungs. College of Surgeons, London, 1842.

The presence of epithelial scales in the air cells was first observed by Mr. Addison *; but that gentleman was unable to determine whether these were ciliated or not; subsequently Mr. Rainey † advanced the statement that healthy air cells contain no epithelium. In sections of recent lungs, it is a very easy matter not merely to determine the existence of epithelium in the air cells, but also the fact of its cylinder and ciliated form and character. Circular and oval epithelial cells also occur: these are most probably ciliated cells in a less advanced condition of development. (See Plate XLVIII. *fig.* 3. and Plate XLIX. *fig.* 2.)

It has been stated that the air cells vary in size. This is the case with even contiguous cells, as may be seen by a reference to the figures: the air cells in the lungs of an adult are also much larger than those of a child.

The fact of the epithelium extending from the bronchial tubes into the air cells, would seem in itself to imply that the mucous membrane also lined them, at least in a modified condition, which is contrary to the opinion expressed by Mr. Rainey.

VASCULAR APPARATUS.

The vascular apparatus of the lungs consists of arteries and veins: these vessels, after numerous ramifications in the interlobular spaces, unite together on the surface of the air cells, through the medium of a beautiful and elaborate system of plexuses, each air cell being furnished with its own separate plexus.

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* Observations on the Anatomy of the Lungs, by Thomas Addison, M.D., 1841. Transactions, Medico-Chirurgic Society.

† On the Minute Structure of the Lungs, and on the Formation of Pulmonary Tubercle, by George Rainey. Transactions, Medico-Chirurgic Society, 1845.

The manner in which the vessels, either arteries or veins, are distributed throughout each lobule is as follows: — first, large branches, after having reached the lobule through the interlobular spaces, extend over an area of several cells (See Plate XLVII. *fig.* 2); from these, secondly, a number of smaller vessels proceed, which run in the spaces between the cells, forming loops around them (See Plate XLVII. *fig.* 3); third and last, from these intercellular vessels the capillaries constituting the plexuses are given off. (See Plate XLIX. *fig.* 3.) This distribution of the vessels is especially evident on the pleural surface of the lung.

From the preceding description it does not appear that the capillary plexus belonging to each air cell is compounded of both venous and arterial capillaries, but that in most cases it consists entirely of capillaries derived exclusively either from a vein or an artery.

It is thus evident that an air cell with its investing plexus of capillaries contains all the essential constituents of an entire lung, and therefore that each air cell may be regarded as a lung in miniature.

It is well known that it is frequently a matter of great moment, in a medico legal respect, to discriminate between a lung naturally inflated and one artificially so: the test proposed and ordinarily employed and relied upon, seems to me to be unworthy of full confidence. I allude to the hydrostatic test: it is stated that, by firm pressure, all the air contained in a portion of lung artificially inflated may be expressed, so that it will sink in water; but that this cannot be done in the case of a lung naturally inflated; a portion of air will always remain unexpressed sufficient to keep it afloat. I see no good reason for this constant difference, since it is perfectly certain that a lung may be most completely and entirely injected with air or fluid, far more completely, I should be inclined to say, than occurs with air naturally inspired, except perhaps during a forced inspiration. Notwithstanding the uncertainty which seems to me to be attached to this test, I yet consider that by a careful examination of the condition of the blood vessels in the two lungs, the question may in most cases be satisfactorily determined, whether has the lung been artificially or naturally extended with air?

Previous to birth, it is known that the circulation of blood through the lungs is of a very limited character, and that it is only after that period, and during the first act or acts of respiration that the great mass of vessels, principally capillaries, become carriers of blood.

The vessels then, in the one case, viz. before respiration, will be almost devoid of blood, and, in the other, after that act, replete with that fluid.

Dependent upon this difference in the condition of the vessels, we shall notice certain distinctive features, both general and microscopical, in the case of the artificially and the naturally inflated lung. The former, after inflation, will be observed to collapse to nearly its previous size on the escape of the air; it will present a pale appearance, especially evident if the lung be cut into, and when examined with a lens, it will be seen that the interspaces between the lobules and cells are pale, not being occupied with red vessels. Now, on the other hand, the latter will be characterized by appearances the very reverse: it, after inflation, will not collapse to nearly its previous size; it will be somewhat red, and the intervals between the lobules and cells will be seen to contain red vessels, in which, as well as in the capillaries, the higher powers of the microscope will reveal the existence of red blood discs.

PATHOLOGY.

Now that the normal anatomy of the lungs is well understood, the several pathological conditions of those organs admit of a precise and satisfactory explanation. The principal diseases of the lungs, upon the exact nature and seat of which the microscope affords, directly or indirectly, satisfactory information, are Emphysema, Asthma, Pulmonary Apoplexy, Pneumonia, and Tubercle.

Emphysema.—The essential pathological and microscopical characters of Emphysema consist in an enlargement and rupture of a greater or less number of air cells, whereby the cavities of several distinct cells become thrown into one, with sometimes the escape of air from the ruptured air cells into the interlobular cellular tissue. When the air cells are simply dilated and ruptured, without any escape of air from them, the Emphysema is lobular; when, on the contrary, the air passes from the cells into the cellular tissue, which unites the lobules to each other, the Emphysema is termed interlobular. It cannot be doubted but that this condition of the lungs interferes very greatly with the efficiency of these organs; the extent of surface over which the air and blood are brought into contact being very considerably diminished.

Asthma. — The microscope has revealed the fact that the smaller bronchial tubes and air cells are principally constituted of a form of elastic tissue, which, possessing marked physical properties, is yet, to a certain extent, under the control of the nervous system. It is then the irregular action and contraction of this tissue, determined partly by physical causes and partly by irregular and unequal impressions arising from internal causes conveyed to this tissue by the nerves, which occasion and account for the distressing and peculiar symptoms of Asthma.

Pulmonary Apoplexy. — Pulmonary apoplexy is simply a highly congested condition of the vessels, which are principally capillary, of the lungs. A congested vessel is of greater diameter than an uncongested one, and, therefore, is capable of containing, and really does contain, a far larger quantity of blood than the vessel in its normal state. There are many stages or degrees of congestion and of pulmonary apoplexy: the congestion may be slight, may engage only one lung or a portion of one; the dilatation of the vessels may be but trifling, and therefore the increased quantity of blood conveyed by them will be but small; or, on the other hand, the congestion may be very great, both lungs may be affected, and the dilatation of the vessels may be considerable; the quantity of blood also contained in such vessels will be very great. In cases of trivial or partial congestion a slight retardation in the progress of the blood only occurs; in the more severe and complete cases the blood accumulates in the vessels to such an extent as that the circulation is totally annihilated, death being the necessary result of such a condition of things.

In what way may the occurrence of this congestion be explained, and what is the cause of the cessation of the circulation? The capillary vessels of the lungs are, of course, incapable of conveying beyond a certain quantity of blood: any causes, therefore, and there are several, which drive in upon the lungs a greater amount of the vital fluid than its vessels are capable of circulating would produce congestion; the first effect of which is an accumulation of blood in the vessels; the second, an enlargement of those vessels, the coats of which are highly elastic, as a necessary consequence of the first; third, a total cessation of the circulation, arising from the rapid aggregation of the blood corpuscles in the vessels. The various degrees of congestion may be followed out with the microscope in the most satisfactory manner in the tongue of the frog, or in the web of the feet of that creature. Some of the vessels will be but slightly dilated; other capillaries which, in their normal state are capable of conveying only a single row of corpuscles, will now be observed to contain two or three rows; in others, again, the blood will have ceased to move altogether.

These several changes in the condition of the blood and its vessels during congestion, are all unaccompanied by structural alterations, by which character congestion may be distinguished from inflammation.

Pneumonia. — The phenomena of congestion precede those of pneumonia, of which indeed it may be considered as the first stage; the second stage of pneumonia consists in the rupture of some of the capillary vessels, and the escape of a portion of their contents (whence proceeds the characteristic rust-coloured expectoration), as well as the effusion without rupture of coagulable lymph through the walls of the vessels, the consolidation of which in the air cells constitutes the condition of the lung known by the name of hepatization: these results are probably necessary consequences of the protracted congestion: the third stage of pneumonia is attended by the formation and excretion of granular cells in large quantities, imbedded in a fibrinous fluid: the excreted matter may be either mucus, constituting the stage of resolution, or it may be pus, when the pneumonia is said to terminate in purulent infiltration: the difference between the two excretions is one of degree rather than of kind. With respect to the nature and origin of the granular corpuscles, some physiologists will have it that they are the white corpuscles of the blood escaped from the vessels — an opinion completely untenable: they doubtless have an origin external to the blood vessels, and are to be regarded as of an epithelial character, representing as a rule the peculiar epithelium of the surfaces or parts from which they emanate.

Tubercle. — The earlier microscopic observers approached the investigation of tubercle, especially of tubercle in the lungs, with the expectation of finding in tubercular matter some peculiar element or structure which should account for the fatality and apparent malignity of that fearful affection, not knowing fully the true structure of the organs of respiration, and therefore not perceiving clearly that this fatality is occasioned rather by the peculiar structure of the lungs themselves, than by any malignity in the character of the tuberculous formation. Some of these observers have even fancied that they have discovered in the matter of tubercle peculiar and characteristic cells: it is now scarcely necessary to remark, that careful and extended microscopic investigation does not warrant any such conclusion.

One of the most accurate views with which I am acquainted respecting the nature of tubercle, is that put forth by Dr. Addison.*

" Tubercles of the lungs," he writes, " are composed of objects originating from blood corpuscles, which have been arrested in their circulation through the minute vessels of the structure of the air cells. So long as this retardation is confined to the colourless corpuscles, the morbid actions which ensue are strictly those of an abnormal nutrition, and various forms of imperfect and degenerated epithelium are the results; but if it extend, so as to interfere with the free circulation of the red corpuscles, we then have all the phenomena of inflammation. No new elementary particles are formed to constitute a tubercle, and although from the insidious nature of the primary actions, from the delicacy of the structure, and the important character of the function of the lungs, the treatment of tubercular diseases must always be attended with more than common difficulties, still there is every reason to believe that they are susceptible of prevention and cure, especially if our efforts for the attainment of these ends be enforced previous to the appearance of a cough, which is not a concomitant of the first stages of tubercular deposition in the lungs."

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* Experimental Researches. Transactions of Provincial Medical, and Surgical Association, vol. xi. pp. 287, 288.

My own views of the nature of tubercle in the lungs differ in one important respect from those of Dr. Addison; that is, with reference to the precise origin of the imperfect and degenerated epithelial cells. Dr. Addison conceives that they are derived immediately from the blood itself, while I consider that they proceed from the epithelium, which has been described as lining the air cells themselves.

A tubercle then I would define as an accumulation of epithelial scales, the imperfect and degenerate representatives of the true epithelial cells of the organ or part in which the tubercle is itself developed.

A tubercle of the lungs, at the earliest period of its formation, is exceedingly small, occupying a single cell only; when this cell becomes filled with tubercular matter, a rupture of its membrane occurs, and thus the extension of the tubercle takes place from cell to cell; this extension at the same time being accompanied by a destruction and displacement of numerous of the capillary plexuses.

After the above description, it need scarcely be observed that tubercles of the lungs are not vascular.

Art. XXI. GLANDS.

Much uncertainty has until recently prevailed as to what really constitutes a gland: some have considered those only as true glands which are furnished with distinct openings or excretory ducts; others again have regarded those organs only as glands which give forth a secretion: the former view of a gland would exclude the vascular glands as well as some others, and the latter, although it would include these, and, doubtless, also every other glandular structure, is not a sufficiently obvious or structural character, the secreted product of glands in many cases being furnished in small and scarcely appreciable quantities, and which again are immediately on their formation, absorbed, in some cases, into the circulation. Again, secretions are supplied by parts and extended surfaces to which, although they are essentially glandular, the term gland would scarcely be applicable; of this nature are the free surfaces of all membranes covered by epithelium, as the mucous, serous, synovial, &c.

We have still then to inquire, first, what are the essential structural elements of which all glandular organs or parts are constituted? and, second, what is the exact definition to be given of a gland?

The researches of modern microscopists have indisputably proved the fact, that, the only essential elements of a secreting structure are *granular cells* and a *circulating fluid,* the secreted product being formed out of the latter by the vital endowments resident in the former.

According to this definition, the blood itself is to a considerable extent glandular, inasmuch as it contains a vast number of granular cells to which the elaboration of the fibrin is, in all probability, due.

Again, the free surfaces of all membranes are glandular; the epithelium covering them constituting the one essential glandular element: the varieties in the size and form of the cells representing this epithelium have been already described in a former chapter of this work.

Following up this general definition of glandular structure, a gland may be defined as a collection or aggregation of granular cells placed in close approximation with a formative fluid, contained, ordinarily, but not essentially, in the blood vessels.

This definition of a gland embraces not merely those glands which are provided with orifices or excretory ducts, but also those which have no such external or apparent channels of excretion, as the vascular and other glands.

While it is certain that secretion takes place in the cavities of the granular cells, as may be actually shown to occur in the hepatic, renal and sebaceous cells, there is much reason to believe from the rapid and continual development and dissolution of successive generations of cells as especially evident in the case of those of the stomach and small intestines, that this secretion is liberated in many instances only by the dissolution of cells themselves. From this view of the relation existing between the secretion and the cells, it would appear that the secretive process is accompanied by an endosmotic action.

In the case of fat cells, the secretion is rarely eliminated, the secretive process is exceedingly slow, and the oleaginous matter is stored up and retained within the cavities of the cells themselves, the growth of the cell membrane keeping pace with the increase in the amount of its fatty contents.

The idea of fluidity is almost inseparably connected with our notions of a secretion: secretions, however, are not essentially fluid, for there are solid secretions as well as fluid; the sebaceous matter of the glands of the prepuce is a solid, and the urine of many serpents, as the boa, is also stated to be solid. There is little doubt, however, but that most and perhaps all secretions are fluid during the act of their formation, and that the solidity acquired by certain of them occurs after their perfection and elimination.

In a strictly systematic arrangement of structures, the majority of the glands might well be described in connexion with the internal and external integuments of the body, the skin, and mucous membrane, since in very many glands, the secreting structure is contained within, but most probably not developed from inverted processes of these tissues. Such an arrangement of the glands, although a very natural one as far as it goes, would yet not embrace all the glands; the vascular and some others would be excluded from it.

The proof of the position that very many glands, and even the most complex ones, are contained in offsets of the various modifications of mucous membrane and outer integument, observers have stated to be derived from an examination of these organs in an embryonic condition, when even, it has been affirmed, the most elaborate and varied of them may be seen as simple follicles or sacks springing from the general membrane covering the skin or lining the internal cavities.

It would appear, however, from recent and trustworthy observations, that the principal glandular organs of the body have each a separate development, and that it is only after they have been more or less completely formed that they become attached to the surface of the skin or mucous membrane, upon which their secretions are poured.

Numerous divisions of glands have been proposed by different writers: the majority of these do not require any special notice: there is one, however, originating with Mr. Goodsir, which would appear to be ingenious and philosophical, which deserves especial mention. That gentleman divides glands into two types or classes; the distinctions existing between which are founded upon observations derived from the study of the early development of these organs.

In the first type of glandular structure, the follicles which are at first distinct from the excretory duct, but which subsequently become united with it, are regarded as parent cells, the granular cells contained within them being secondary formations, which are continually in process of development, springing from a germinal spot situated either at the bottom of the follicle, if this be short, or over its entire surface, if the follicle be tubular: in this class the follicle is a permanent structure.

In the second type, the follicle is also a parent cell, but is not a permanent structure, and having attained its maturity, it bursts, discharges the secondary cells contained within it, and finally shrivels up, its place being supplied by other similarly organized cells.

In this type but one gland is included — the testis.

The arrangement of glands proposed below in a tabular form would appear to be one of the least objectionable as well as the most practical for purposes of description.

CLASSIFICATION OF GLANDS.

a. UNILOCULAR GLANDS.

Follicles.
Stomach Tubes.
Soliary Glands.
Aggregated Glands.

b. MULTILOCULAR GLANDS.

- Sebaceous Glands.
  - *Meibomian Glands.*
  - *Glands of Hair Follicles.*
  - *Caruncula Lachrymalis.*
  - *Glands of Nipple.*
  - *Glands of Prepuce.*
- Mucous Glands.
  - *Labial Glands.*
  - *Buccal Glands.*
  - *Gingival Glands.*
  - *Lingual Glands.*
  - *Tonsellitic Glands.*
  - *Stomach Glands.*
  - *Tracheal Glands.*
  - *Vaginal Glands.*
  - *Uterine Glands.*

c. LOBULAR GLANDS.

- Salivary Glands.
  - *Pancreas.*
  - *Parotid Glands.*
  - *Submaxillary Glands.*
  - *Lachrymal Glands.*
- Mammary Glands.
- Liver
- Prostate Gland.
- Cowper's Glands.

d. TUBULAR GLANDS.

Brunner's Glands.
Sudoriferous Glands.
Axillary Glands.
Ceruminous Glands.
Kidneys.
Testes.

e. GANGLIONARY GLANDS.

Compound.	*Simple.*
Brain and Cerebellum.	Ganglia of Encephalic Nerves.
Medulla Oblongata and Spinal Cord.	Ganglia of Sympathetic Nerves.

f. ABSORBENT GLANDS.

Lacteal Glands.
Lymphatic Glands.

g. VASCULAR GLANDS.

Spleen.
Supra-renal Capsules.
Thymus.
Thyroid.
Pituitary Body.
Pineal Gland.

h. GERMBEARING GLANDS.

Ovaries.

It is doubtful whether the glands admit of any strictly natural and at the same time convenient classification. The more simple glands pass by almost insensible gradations into the more complex, thus leaving but few salient points available for purposes of division. The separation of the multilocular from the lobular glands is to a great extent arbitrary, and is adopted simply from its convenience. Perhaps the best division which could be proposed of those glands which are provided with excretory ducts or openings, is into follicular and tubular glands.

It is very probable that one of the organs introduced into the division of lobular glands, viz. the liver, will hereafter have to be removed from that division and placed by itself near to the vascular glands, should some recent researches in reference to the termination of the biliary ducts be confirmed.

It is also probable that further research will disclose the fact that certain of those glands arranged as mucous glands do not all possess precisely the same structure.

UNILOCULAR GLANDS.

FOLLICLES.

Crypts and follicles are inverted, and sometimes tubular prolongations of one variety of mucous membrane termed *compound*, and to which that of the alimentary canal, the gall bladder, the uterus and the Fallopian tubes belong.

In the stomach and in the large intestines these follicles are so closely set in the membrane, that from the mutual compression exercised upon each other, they assume a more or less angular figure; in the small intestines there are fewer follicles in consequence of the great number of villi present in these, and they are not angular, but round. These follicles, which, in the small intestines, are called the follicles of Lieburkühn, are met with under two very different conditions; in each of which they present a very distinct appearance, being in the one case, that is, in their perfect state, lined by epithelium, and in the other being destitute of this epithelium. (See Plate L. *figs.* 1. 6.)

The epithelium lining the follicles of the alimentary canal, is of the same kind as that which covers the interspaces between the follicles, and is of the conoidal variety. It lines the entire follicle with a beautifully regular layer of united epithelial scales, which are so large that they nearly fill up the cavities of the follicles, a small circular channel only being visible in each; this is usually occupied by the mucus secreted by the cells, and appears at the mouth of each follicle as a mere depression, surrounded by a circle of radiating epithelial scales.

To see the epithelium in the follicles of the human stomach, and even to see the follicles in the mucous membrane of this organ at all, requires that it should be examined immediately after death, as the lapse of a few hours is sufficient to allow of the action of the gastric juice to such an extent as to dissolve the follicles entirely.

The follicles dip into the thickness of the mucous membrane to a variable extent in the small and large intestines; their extremities reach nearly to the submucous cellular tissue, and in the lower part of the rectum they are much elongated, and continued for some distance into the submucous fibrous tissue between the mucous and muscular coats; the follicles usually terminate in rounded and sometimes even in dilated and bifurcated extremities. (Plate L. *fig.* 7.)

The object attained by these innumerable follicular inversions of the mucous membrane of the stomach and intestines is obvious, viz. a greatly extended surface for secretion.

The mucus with which the intestinal canal is so abundantly provided, is chiefly secreted by the epithelium contained in these follicles.

Todd and Bowman thus describe the epithelium of the stomach cells in the Physiological Anatomy: " They (the epithelial particles) seem to lie in a double series, the deeper being in course of development, while the more superficial is in course of decay. It has appeared to us that each particle when arrived at maturity has, besides the nucleus, granular contents enclosed, and that at a subsequent period the granular contents escape at the free extremity by a debiscence or opening of the wall, at that part, having the transparent husk with its nucleus subsisting for some time longer. The clear structureless mucus which is almost always found occupying the cells and covering the surface of the membrane seems to be the altered contents of these particles after their escape, for the uniform existence of a minute cavity in the centre of it, when it fills the cells, shows that it has oozed out from every part of their wall so as gradually to fill them up."

The ridges or spaces between the follicles of the stomach and large intestines in the human subject are occupied with a plexus of vessels larger than capillaries (see Plate LI. *fig.* 1.); these are situated on the deep surface of the basement membrane, while the epithelial scales are upon its superficial surface: in the cat, and many other animals, the interfollicular spaces, instead of being occupied by a plexus of vessels, contain only a single vessel, which freely inosculates with the neighbouring vessels, thus mapping out the spaces between the follicles into somewhat irregular hexagons. (See Plate LI. *fig.* 2.)

STOMACH TUBES.

The tubes of the stomach are prolongations of the basement mucous membrane lining the follicles of that organ. (See Plate L. *figs.* 3, 4, 5.)

These tubes take a parallel course, end in irregularly dilated extremities, are arranged in sets of three, four, or five tubes, each of which corresponds with a follicle, and represents the number of tubes which open into that follicle: it is only, however, near their entrance into the follicles that they are thus parcelled out: at their termination they would appear to be independent of each other, and to be separated by equal intervals, as represented in Plate L. *fig.* 3.

The stomach tubes, unlike the mucous follicles, are filled with spheroidal or glandular epithelial cells: these cells, however, do not quite fill up the cavity of the tubes, but leave in the centre of each a channel or canal, along which the fluid secreted by the cells flows, until, at last, it reaches the follicle into which it is poured.

The fluid secreted by these cells is, doubtless, the true solvent or gastric fluid.

The tubes I find to exist not merely in the stomach, to which they are generally described as exclusively belonging, but also in the upper part of the duodenum, which shows that in the human subject, this portion of the intestine is to be regarded as a kind of second stomach. I have observed the occurrence of these tubes more than once both in the duodenum of man, as well as of other mammalia.

The fact of the mucous membrane lining the duodenum being frequently dissolved some hours after death in the same manner as that of the stomach would in itself lead to the inference that these tubes were present in the upper part of that division of the alimentary canal.

Messrs. Todd and Bowman figure the tubes as more or less branched previous to their entrance into the follicles, an observation which I can confirm: these gentlemen also thus describe a modification of the follicles and tubes near to the pylorus. "Here, in many of the lower animals which we have examined, for example, in the dog, and it may with probability be inferred, in man also, a change occurs in a very gradual manner, but evidently of an important kind. The membrane is of a paler tint, and its cells seem not to terminate at once in the true stomach cells already described, but are prolonged into much wider cylindrical tubes, lined with the same columnar epithelium, and descending nearly or altogether to the deeper surface of the compound membrane. For the most part, these prolongations of the cells — or, as we shall term them, *pyloric tubes* — end, at length, in very short and diminutive true stomach tubes; but we have likewise found them terminating in either flask-shaped or undilated extremities, lined throughout with the subcolumnar variety of epithelium."

The stomach tubes are each surrounded by a plexus of vessels.

FALLOPIAN AND UTERINE TUBES.

Tubes somewhat similar to those of the stomach exist, according to the observations of Mr. Bowman, in the mucous membrane of the Fallopian tubes and stomach.

"The lining membrane of the Fallopian tubes, as well as that of the uterus, is of a compound nature, especially during gestation, and consists of tubules arranged vertically to the general surface. It is to be observed that the cilia only clothe the general surface, and that the epithelium lining the tubules is spheroidal or intermediate between that and the prismatic. It is a form of the glandular variety, and bears no cilia." *

SOLITARY GLANDS.

The solitary glands are scattered irregularly over nearly the whole surface of the small and large intestines; they vary considerably in size, the larger glandulæ being found principally in the lower portion of the large intestines, and admitting of easy recognition without the aid of lenses, while the smaller glands, situated in the lesser bowel, are scarcely visible, except in states of disease, when their cavities are filled with secretion. Plate LII. *fig.* 6. is a drawing of these glands as they appeared in a case of muco-enterite in one of the small intestines, while Plate LI. *fig.* 6. is a representation of them as found in the larger bowel in a case of English cholera in a child.

These glands are simple sacks or cells filled with a fibrinous fluid, containing imbedded in it innumerable spheroidal and granular cells somewhat smaller than ordinary mucous corpuscles.

I have observed these glandulæ both with and without central orifices; these have been more frequently absent than present; hence it is very probable that their normal condition is that of a closed cell, and that when these cavities become filled with secretion, they rupture, and thus permit their contents to escape, the orifice subsequently closing up again.

Not unfrequently, these glands in certain animals, but not generally in man, are observed to be surrounded by a circle of short and tubular cæcæ; these by some observers are regarded as follicles of Lieburkuhn, and it is uncertain whether their bases communicate with the cavities of the glands or not, but it is generally stated not to communicate with the interior of the glandulæ.

The distribution of the vessels around these glands presents nothing remarkable.

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* Cyclopedia of Anatomy and Physiology, Art. "Mucous Membrane," vol. iii.

AGGREGATED GLANDS.

The aggregated, agminated or Peyers glands are present in the lower portion of the ilium only.

They occur in patches of various sizes, each of which is made up of a considerable number of distinct glandulæ, having much the same structure, form and volume, as the solitary glands, an aggregation of which they may be considered to be. These patches may be readily recognised without the assistance of glasses.

In the "glandulæ aggregatæ," central apertures are occasionally present, and they are not unfrequently surrounded by the short tubular cæcæ already spoken of: the interspaces between the glandulæ in the human subject are very generally covered with villi. The size and limits of these glands may be best determined by injection.

When examined with glasses as they lie in the mucous membrane *in situ,* they appear rounded and flat, presenting many dark spots, the nature of which is not understood: when viewed sideways, they are seen to be really of a flask-shape, the narrow extremity of the flask being turned towards the surface of the mucous membrane. (Plate LII. *figs.* 3, 4.)

In inflammation of the mucous membrane of the ilium, a frequent concomitant of low fevers, these glands are often found to be entirely eaten away, but sometimes they are only so far eroded as to present in place of closed glands, a number of open cells or follicles.

MULTILOCULAR GLANDS.

SEBACEOUS GLANDS.

The sabaceous glands are very generally distributed over the surface of the body, probably not less so than the sudoriferous glands, there being but two situations in which they are stated to be absent, viz., the palms of the hands and the soles of the feet. On all other surfaces of the body the two kinds of glands are constantly associated together, the sudoriferous being much more numerous than the sebaceous glands.

They are found especially more or less deeply imbedded in those portions of integument which are copiously clothed with hair, as the scalp, whiskers, beard, axilla, pubis, scrotum, and perineum. They also exist, however, in abundance in certain situations not usually invested with hair, as in the integument of the forehead, face, and nose, in the meatus auditorius externus of the ear, and for a certain distance up the anterior openings of the nares: those situated around the nipple of the female are particularly large, while those of the prepuce are not merely of considerable size, but yield a solid and unctuous secretion of a peculiar and penetrating odour.

Those glands which exist in situations which are naturally clothed with hair always open into the hair follicles, while those present in parts not furnished with such a covering, yet nevertheless open into follicles which, although from the absence of hairs they cannot be called hair follicles, must yet not be regarded as essentially distinct from hair follicles, since they in some cases do really contain hairs.

As there are varieties of sebaceous matter, so are there sebaceous glands which differ structurally from each other; thus the cerumen glands of the ear present a conformation typically distinct from all other sebaceous glands, belonging to the tubular type of glands, with which they will be described.

There are characters, however, in the possession of which all sebaceous glands agree, save, perhaps, the cerumen glands, and these are in the semi-solid nature of their secretion and in the mode of its formation and elimination.

The secretion of the sebaceous glands, like other secretions, is formed within the cells, which are very large, and in which it exists in the form of little spherical and shining particles of various sizes; these cells, when filled with the secreted matter, are thrown off without rupture from the glands in which they have been formed probably by the development of fresh cells behind them, so that in general the sebaceous secretion consists of an aggregation of such eliminated cells. Some few of the cells, however, do burst and allow of the escape of their contents.

The sebaceous cells, like other secreting cells in an early stage of development, are granular and nucleated.

In the character of their secretion, the sebaceous glands exhibit considerable affinity with the mammary glands. The milk globules, however, are formed without the cells, and not within them, as is the case in the sebaceous glands.

The sebaceous glands, exclusive of the ceruminous, manifest considerable variety in size, form, and arrangement. They may be thus arranged: first, The Meibomian glands; second, The glands of the Hair Follicles, the hairs being in some cases present in the follicles, and in others absent from them; third, The glands of the Nipple; fourth, The glands of the Prepuce; and fifth, The glands of the Carunculæ Lachrymales.

Meibomian Glands.

The Meibomian glands are situated on the inner surface of the eyelids, between the conjunctiva and the tarsal cartilages; they are of an elongated form, and disposed in a vertical manner.

The number of these glands in the two eyelids is usually not less than forty; in one instance I counted eighteen in the upper eyelid, and twenty-two in the lower. Their general form and arrangement differs somewhat in the two eyelids; thus, in the lower, they are of nearly equal length, and are arranged in a parallel manner, while in the upper they are much longer, almost as long again, their origins describing an arc; and in place of being disposed parallelly, they radiate from each other. These differences depend upon the corresponding differences in the size and form of the two eyelids.

Each gland consists of a number of follicles or sacks which open into a central canal, which pierces the conjunctival membrane at the margin of the tarsal cartilages. The follicles are usually filled with cells, which may be seen through their walls. These cells present a bright and shining appearance from the oily nature of their contents. (See Plate LIII. *fig.* 2.)

Glands of Hair Follicles.

The external surfaces of the body, with few exceptions, the palms of the hands and soles of the feet being the principal of them, are covered with the hair follicles, which are placed at tolerably regular distances from each other, and the apertures of which are visible even without the aid of glasses.

The hairs which issue from these follicles differ in character according to their situation; those of the scalp being long and fine; those of the beard, &c. short and thick; while those clothing the general surface of the body are not merely short, but also exceedingly slender.

In certain situations the hair follicles are frequently without hairs, as on many parts of the face; this, however, is the exception rather than the rule, as very fine hairs are generally present over the entire surface of the face.

It is into these hair follicles that almost all, if not all, sebaceous glands open.

The sebaceous glands of the hair follicles consist of several distinct cells or sacculi, each of which has a separate excretory duct; two or more of these ducts, there being sometimes three, four, or five, open into one common duct, which last opens upon the sides of the hair follicles: there are usually two, but sometimes more of these common ducts, and very frequently several of the primary excretory tubes open directly into the hair follicle. The ducts are large, and usually straight; but occasionally, like those of the sudoriferous glands, they are slightly spiral. (See Plate LIII. *fig.* 1. 3.)

Those sacculi which open into the hair follicles by distinct ducts are to be regarded as separate glands. In the hair follicles of the scalp the glands are usually binary.

The glands of the hair follicles are not confined to the external surfaces of the body, but are continued for a certain distance along several of the outlets. Thus, they occur in the lower part of the anterior openings of the nares, in the meatus auditorius externus, in the palpebral conjunctiva, in the caruncula lachrymalis, in the vulva, and on the interior surface of the prepuce.

The sebaceous glands vary greatly in size, being, in certain situations, much larger than in others, as in the eye-lids, ears, nose, around the nipples, especially of the female, and on the inner surface of the prepuce.

The cells contained within the ordinary sebaceous glands differ, in no respect, from those of the Meibomian glands already described. It is in the hair or sebaceous follicles that the well-known parasite, the Steatozoon Folliculorum, whose economy has been so well described by Mr. Wilson, is found, it being placed in these in an inverted position, the head being turned inwards, as though the animalcule had crept into the follicles from without. Many of the follicles frequently contain more than one parasite.

Caruncula Lachrymalis.

The caruncula lachrymalis is usually described as formed of a single large sebaceous gland: it is not so, however, but is constituted of a considerable quantity of mixed fibrous tissue and of blood-vessels, in the midst of which several, usually four or five, distinct sebaceous glands are imbedded.

These glands, like other sebaceous glands, also open into follicles, which are certainly hair follicles, although, in the human subject, they do not usually contain hairs. That they are really hair follicles, however, is proved by the fact that in the sheep minute hairs do constantly issue from them.

Glands of Nipple.

The sebaceous glands imbedded in the integument which forms the areola around the nipple so conspicuous in the female, differ from other sebaceous glands principally in their larger size, which allows of their being readily perceived without the assistance of glasses.

Glands of Prepuce.

The glands of the prepuce are also remarkable for their large size, as well as for the peculiar characters of the secretion which they furnish; one of these being its semi-solid consistence; a second, its penetrating and remarkable odour.

MUCOUS GLANDS.

The great agents in the secretion of mucus are the cells contained in the *follicles* with which all compound mucous membranes are furnished; there is, nevertheless, a description of gland very generally distributed, differing anatomically from the follicles, also called mucous, and which is, in like manner, supposed to furnish a mucous secretion. It is, however, very probable that as there are structural differences between the two, so are there differences in the nature of the secretion elaborated by them.

Before entering into a description of the mucous glands, it will not be out of place to present to the reader the results of some additional researches on the structure of mucous membranes: at a former page of this work it was stated that mucous membranes may be divided into simple and compound according as they contain follicular involutions, or are destitute of such inverted processes; and that the compound membranes were that of the alimentary canal from the cardia downwards, of the gall bladder, and of the uterus and Fallopian tubes, according to Bowman. Further observations have, however, shown me that on the one side the mucous membranes of the mouth (including that which lines its roof, which invests the tongue, and which covers the tonsils, uvula, and epiglottis), of the œsophagus down to the cardia, of the vagina and neck of the uterus, of the vesiculæ seminales, as well as the Schneiderian membrane, are also compound; while, on the other, the mucous membranes of the Eustachian tubes, of the trachea, and bronchial tubes, of the bladder, and of the unimpregnated uterus, and Fallopian tubes, are simple mucous membranes.

The follicles of the mouth are somewhat large, scattered, and mostly simple; those of the œsophagus are small, and not unfrequently divided into branches near their extremities; the follicles of the vagina resemble somewhat those of the œsophagus, but are much more branched, very many of the follicles terminating in several offsets, and becoming in fact perfect multilocular glands: the follicles of the Schneiderian membrane are the largest hitherto noticed, and appear to be simple inversions of the membrane.

It has been stated that the mucous membrane of the uterus and Fallopian tubes is simple, in which respect there is a difference between the observations of the author and those of Mr. Bowman. Considerable pains have, however, been taken to arrive at the truth; and it is conceived that the mucous membrane of the parts cited affords one of the best examples which could be given of a simple and delicate mucous membrane. The membrane covering the lips of the uterus and lining the orifice of that organ is, however, like that of the vagina follicular, the follicles in the latter situation being particularly large; and it is these follicles which yield the thick and tenacious mucus which usually more or less completely plugs up the uterine orifice.

Mucous glands occur in very many and different localities, in several of which they have received distinct names taken from the parts or situations in which they have been found. Thus we have *labial, buccal, tonsillitic, lingual,* and *tracheal* glands: following up a similar kind of nomenclature for these glands, we might add to this list *Eustachian, palatine, pharyngial,* and *bronchial* glands, also *glands of the uvula.*

In the roof of the mouth the mucous glands are very numerous, forming almost one continuous glandular layer, provided with many orifices disposed at tolerably regular distances from each other: they are also numerous in the tonsils, but much less so in the uvula: on the dorsum of the tongue mucous glands occur but very sparingly, and mostly near the root of this organ.

There are some few situations in which mucous glands have been described as present, in which they would appear to be entirely absent; as on the margins of the gums, where they have been called *gingival*, in the uterus and vagina, where they have been named *uterine* and *vaginal* glands: in the stomach, also, where they are known as the *lenticular* glands, they are very frequently wanting.

There are also certain glands which have not been generally placed in the category of mucous glands, which, nevertheless, are really structurally identical with them: of this nature, are *Brunner*'s and *Cowper*'s glands.

From the preceding observation, it follows that Brunner's and Cowper's glands should be described with the other mucous glands: it will, however, be seen hereafter that the former present certain resemblances to the tubular and the latter to the lobular glands.

Messrs. Todd and Bowman * regard the mucous glands as identical in structure, and probably in function also, with the salivary glands: that they are not salivary glands, however, may be shown, first, by the anatomical differences which may be pointed out as existing between mucous and salivary glands, as well as, secondly, by the fact that mucous glands occur in situations — as in the trachea, &c. — where they could serve no purpose as salivary glands. Mucous glands occur in two forms: a simple and compound form. In its simple or simplest form, a mucous gland consists of a single duct in communication, at its origin, with a saccated membrane, each sacculus of which forms an imperfect follicle. In its compound form, it consists of several ducts, each of which, at its origin, is in like manner in connection with a bunch of incomplete follicles.

The chief anatomical characters which distinguish mucous glands from the salivary, to which, indeed, they bear considerable resemblance, depend upon the fact that, in the mucous glands, the follicles are incomplete; that is, they open into each other and into a common central cavity, from which the single efferent duct proceeds; while in the salivary glands each follicle is a distinct body of a rounded or oval form, and provided with a small primary efferent duct.

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* Physiological Anatomy, page 182.

Independent of the important differences indicated in the preceding paragraph, there are others, viz. the larger size of the follicles of the mucous glands and the coarser and firmer texture of the membrane which constitutes their parietes.

That the follicles do really communicate with each other is proved by the numerous circular apertures which they frequently present, and which reminds one of those of the air-cells of the lungs. (Plate LIII. *fig.* 4.)

The epithelium contained within the follicles is very small, the majority of the cells being spherical.

The membrane of the follicles would appear to be fibrous, and is sufficiently resisting to preserve their form under ordinary pressure and manipulation.

BRUNNER'S GLANDS.

These glands have been already referred to under the head of mucous glands, with which they are structurally identical.

I was led, for a short time, into the error of arranging them with the tubular glands, in consequence of observing that each of the larger glands of Brunner was generally furnished with several tubular ducts; and this led me at first to infer that they were formed entirely upon the tubular type, which is not the case.

In those instances in which more than one duct proceeds from what appears to be a single gland, this gland is not really simple, but compound; that is to say, it is formed of several clusters of follicles held together by fibrous tissue, and from each of which a separate efferent duct proceeds.

The glands of Brunner occur only in the duodenum, and occupy usually the upper two thirds of that intestine: their number and extent of distribution vary, however, in different subjects.

For further particulars, see the description of the "Mucous Glands."

COWPER'S GLANDS.

Cowper's, or the antiprostatic, glands are, as already mentioned, mucous glands, being the largest examples of this description of gland met with in the human body.

The description given of these glands by authors in general, their large size and their apparent constitution of lobules, were the reasons which led to their being temporarily classified with the lobular glands.

The description given of the mucous glands applies in every respect to these.

A knowledge of their true structure and relationship explains their use, concerning which many vague conjectures have been hazarded.

LOBULAR GLANDS.

SALIVARY GLANDS.

The salivary glands include the parotid, submaxillary, and lingual glands, together with the pancreas.

These several glands resemble each other very closely in structure, as well as in the characters of the secretions furnished by them.

The salivary glands consist of lobes and lobules, on the surface of which the blood-vessels ramify; the lobes are made up of the lobules, and the lobules themselves consist of follicles of a rounded or oval form, and each of which is furnished with a minute efferent duct, which, uniting with the other ducts of the same size, forms other larger ducts, and these, uniting again with others of still larger calibre, at length form, by their union, the main excretory tube of these organs. (Plate LIV. *figs.* 1, 2, 3, 4, 5.)

The follicles contain numerous minute granular cells; and those of the pancreas, in addition, frequently many shining globules of an oleaginous character.

Such is a brief description of the salivary glands in their adult form: in their embryonic condition, however, they do not consist of lobes and lobules, but the terminal efferent ducts end in single follicles, which afterwards become multiplied, until at length clusters of them appear,—the incipient lobules. (Plate LIV. *figs.* 1, 2.)

The structure of these glands may be readily followed out without the aid of injection.*

LACHRYMAL GLANDS.

These glands resemble the salivary in all essential structural particulars: they are, however, separated from them in consequence of the difference in the character of the secretion which they furnish.

MAMMARY GLANDS.

The mammary glands do not require any lengthened description, since they also are formed upon precisely the same type as the salivary and lachrymal glands.

The principal structural difference has reference to the efferent ducts. Each salivary gland is furnished with but a single excretory duct, while to each mammary gland there are as many as eight or ten ducts which open on the apex of the nipple: the ducts of the mammary gland are also remarkable for their great capacity, for it is in them that the milk principally collects when it is allowed to accumulate.

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* It will be observed, that the above description of the salivary glands agrees closely with that ordinarily given. An examination of these glands instituted since this description was in type, has convinced me that they approach in organization very nearly to the mucous glands of which they are to be considered as a variety. The salivary glands differ indeed from the mucous in the particulars already mentioned, viz. in the less size of the follicles, and in their more complete shape, but nevertheless are formed upon a similar type of organization. The efferent duct with which each of the follicles of the salivary glands is said to be furnished is so short, that it in very many instances scarcely deserves the name of such; the general arrangement is that of a number of follicles almost sessile, clustering around the terminations of the salivary ducts.

When the follicles of a mammary gland in an active state are examined, vast numbers of milk globules of various sizes will be perceived within them; and lying in the midst of these, the small granular secreting cells will be seen: these, however, do not contain milk-globules, from which it follows that the milk corpuscles are not formed within the granular cells, but external to them, although still within the cavity of the follicles. (Plate LIV. *figs.* 3, 4, 5.)

Mammary glands exist in the human male as well as female breast, the essential structure being the same in both, as proved by the many cases now on record, in which infants have been suckled by men.

In childhood and old age the mammary glands consist of white fibrous tissue in the midst of which traces only of the follicles can be perceived.

Numerous lacteals arise from the neighbourhood of the follicles; by these, the more watery parts of the milk are absorbed when this is retained for any length of time within the breast, and in this way the distension of that organ is from time to time relieved.

LIVER.

The liver has been described as consisting, like the other glands of the lobular form, of lobes, lobules, and follicles or acini; and indeed in some of the lower animals, this organ has such a constitution. It has, nevertheless, recently become a matter of very great doubt whether in the Mammalia, at least, the same type or organization prevails, and whether the structure of this gland in this class of animals is not of a totally different kind.

The mammalian liver consists indeed of lobes and lobules, but the question is as to the existence of the follicles or acini furnished with their efferent ducts.

In the adult liver, the division into lobes, even, is essentially arbitrary, so that, in fact, it is of lobules alone that the liver is entirely composed.

Lobules. — The lobules of the liver are aggregations or masses of granular or secreting cells, of a more or less angular form, first resting upon, and then traversed by, branches of the hepatic vein, and enclosed on all sides by a process of the capsule of Glisson. The intervals separating the sides of two lobules from each other are called *interlobular fissures*, and those which exist where three or more lobules touch each other, *interlobular spaces.*

These lobules, for the most part, are perfectly distinct from each other; nevertheless not unfrequently two of them are more or less united together, as is seen especially on the surface of the liver, and in preparations in which the hepatic system of vessels has been injected. (Plate LIV. *fig.* 6. Plate LV. *fig.* 1.)

The lobules of the liver are of sufficient size to be easily recognized with the unassisted sight: they vary, however, in dimensions, not merely in the liver of different animals, but likewise in that of the same: in some animals, also, as in the rabbit and pig, their form, as well as their size, may be clearly defined; and in these they are evidently angular. (Plate LV. *fig.* 1.)

Such is a brief description of the lobules of the liver: the supposed follicles or acini are nothing more than the intervals between the meshes of the capillary vessels which ramify through the substance of the lobules, and the outlines of which vessels may be readily followed, even without the aid of injection, their course being indicated by a number of dark lines.

Mr. Kiernan supposed that the acini were really follicles, and that they occupied the spaces which he conceived existed between the meshes of his lobular plexus of biliary ducts.

The secreting apparatus of the liver consists not only of lobules and their component cells, but also of biliary ducts and gall bladder.

Biliary Ducts. — In his admirable paper on the liver, inserted in the Philosophical Transactions for 1833, Mr. Kiernan describes the biliary ducts as terminating in the substance of the lobules in a complicated network of minute biliary vessels, which he termed the lobular biliary plexus. Much doubt, however, has recently been cast upon the accuracy of this description, notwithstanding that it has received the confirmatory testimony of very many high microscopical authorities.

The first observer who, I believe, expressed doubts of the existence of a lobular biliary plexus was Mr. Bowman, to whose numerous microscopical researches, science is so much indebted.

More recently still Dr. Hanfield Jones, in a paper "On the secretory Apparatus of the Liver*" has not merely expressed the same doubts, but has entered fully into the reasons on which his opinion is based.

Dr. Jones founds his belief of the non-existence of a lobular biliary plexus upon the following observations: —

> "First, the non-existence of basement membrane in the interior of the lobules which, in common with Mr. Bowman," he writes, "I have been unable to detect; yet were this simplest constituent of a duct present it could hardly escape notice, especially as in other glands it admits of being readily demonstrated; at the broken margin of a lobule it may be well seen that the broken extremities of the linear series are quite free, and exhibit no trace of any containing membrane. Secondly, if the margin of a lobule be carefully examined, where it forms the sides of a fissure, the basement membrane may often be clearly seen, and through its transparent texture the terminal cells of the linear series are easily distinguished, resting against and contained by it. Now were the membrane inflected to form lobular ducts, surely some indentation or irregularity would be visible at the margin of the lobule, but I have often traced the outline carefully without observing any such. A third proof is supplied by the result of some experiments which I made on rabbits. I tied the duct. com. choled., and shortly after death, which took place at periods varying from two to four days, I examined their livers: these organs were found to be beset on the surface and throughout their substance with numerous spots of deep yellow colour, evidently produced by accumulation of bile: a section of these spots, examined under the microscope, showed that they were very partial, never extending throughout the whole of a lobule, but frequently situated in two or more adjacent; their outline was always well defined, and not the slightest appearance of a distended plexus of ducts could be observed. This last evidence appears to me conclusive. I can hardly conceive, that if any plexus of anastomosing ducts existed, the accumulation of bile should take place in definite spots, and those not always situated in a single lobule, but in two or three adjacent."

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* Philosophical Transactions, 1846.

Of the proofs of the existence of a lobular biliary plexus, supposed to be derived from injection, it may be remarked, that these are, in all probability, fallacious, the injection escaping from the extremities of the biliary ducts, and passing into, generally, branches of the portal vein, from which it extends irregularly into the lobular capillary plexus, and it is this plexus filled with injection from the biliary duct, that Mr. Kiernan, it appears to me, took for a lobular biliary plexus. It still, however, must be regarded as a singular circumstance that the injection should so generally pass, after its escape from the ducts, into blood vessels, in place of becoming extravasated around the apertures of the ducts from which the injected material has escaped.

Presuming it, then, to be concluded that there is no lobular biliary plexus, let us next inquire in what manner the biliary ducts do really terminate.

From the further researches of Dr. Hanfield Jones, contained in a recent paper communicated to the Royal Society, and entitled "On the Structure and Development of the Liver," it would appear that the biliary ducts terminate in the vertebrate series of animals in the interlobular fissures and spaces in closed and rounded extremities. (Plate LVII. *fig.* 1.)

If a branch of the hepatic duct be taken up with the forceps, it may, by delicate manipulation, be dissected out from the surrounding parenchymatous tissue. A branch thus prepared, when placed under the microscope, will be seen to be composed of numerous ramified biliary ducts of various sizes: the extremities of the majority of these are even broken off; but several are evidently entire, and these are rounded, as represented in Plate LVII. *fig.* 1.

These ducts are not simple tubes, formed of basement membrane, but are lined by a regular layer of epithelial scales: these serve to secrete the mucus, which partly occupies them; and their presence accounts for the great difficulty experienced in getting the injection to flow along the ducts.

The experiment of dissecting out a branch of the hepatic duct from the parenchymatous tissue of the liver is most readily performed in the soft livers of most fish; as the plaice, sound, &c.; but it may be also effected in the livers of the various mammalian animals.

The author has repeatedly examined branches of the hepatic duct thus prepared, and his own independent observations fully corroborate those of Dr. Hanfield Jones, to whom, for his very carefully conducted inquiries on the intimate structure of the liver, physiological anatomists are much indebted.

The mucous membrane lining the larger hepatic duct is, according to the observations of Mr. Kiernan, follicular.

Secreting Cells. — The secreting structrue of the liver, as of all other truly glandular organs, is cellular, the majority of the cells being perfect, and consequently nucleated, but some few consisting of nuclei only, the most essential element of the cell. Each cell may contain more than one nucleus.

These cells are disposed in series, which radiate from the centre of each lobule, occupied by the lobular hepatic vein: the radii are not formed of single rows of cells placed simply end to end, but the cells frequently partially overlap each other. (Plate LIV. *fig.* 6.)

This linear disposition of the cells would appear to be determined by the radiated arrangement of the vessels which proceed on all sides from the central hepatic vein.

Dr. Jones considers that this arrangement of the cells is connected with the secretion of the bile, and that it facilitates the transmission of this fluid from the centre to the circumference of the lobules: when it has reached this it is discharged into the interlobular fissures and spaces, to be absorbed into the ducts by an endosmotic action determined by the denser mucoid fluid contained within them.

Dr. Hanfield Jones has also observed that frequently the cells are not merely disposed in linear series, but that they likewise coalesce with each other by their opposed margins, whereby the cavities of several cells are made to communicate with each other. This union of the cells Dr. Jones considers to be intended to facilitate still further the transmission of the bile along the series of cells; and he seems disposed to regard it if not absolutely essential to this transmission, yet as of very general occurrence. There can be no question, however, but that, in the great majority of cases, the bile is passed from cell to cell independent of any such union: this is proved by the exceeding rarity of the occurrence of rows of cells united in the manner described and figured by Dr. Jones.

The same accurate observer considers that the first secretion of bile takes place in the most central cells of the lobule, and that this fluid is accumulated in the greatest quantity, and its elaboration perfected, in the marginal cells of the lobule. These opinions are founded upon the following experiments and observations: thin sections of the liver of a rabbit being examined, the ductus communis choledochus of which had been tied twenty-four hours before death, it was manifest, in almost every instance, that accumulation of bile had taken place in the centres of the lobules, as indicated by a yellow zone of some width surrounding the intralobular vein. Now this case, in the opinion of Dr. Jones, presents the earliest effect of interruption to the flow of the secretion; and the appearance described seems to point out the exact spot where the secretion had its origin, viz. in the commencement of the rows of cells surrounding the central axis of the lobule, as represented by the lobular hepatic vein: again, in many livers, a remarkable difference may be observed in the condition of the marginal cells and those placed more centrally; while the latter have appeared of their usual pale or light yellow colour, and have contained but one or two minute oil globules, the former have presented a darker and more opaque appearance, arising from the presence of numerous oil globules.

These observations, especially when considered in connection with the mode of termination of the bile ducts, render it almost certain that the secreting process reaches its termination near the margin of the lobule.

Dr. Jones recognises an *active* and a *passive* condition of the lobules of the liver, and thus describes the differences in the appearances of the margins of the lobules in the two states: —

> "The appearance which the margin of a lobule presents when the process of secretion has been proceeding actively, differs much from that which is observed when the lobule, so to speak, is quiescent: in the latter case, as I have described it, the margin is well defined, and bounded by a distinct basement membrane; while the terminal cells of the linear series contain few and minute oil globules, and do not appear to project outwards in any degree: in the other case the margin of the lobule has an opake cloudy appearance from the multitude of oil-globules. Several cells are seen projecting into the cavity of the duct, giving the wall occasionally a tuberculated appearance: these cells contain oil-globules, and their wall is sometimes so extremely delicate as to be barely perceptible even under a high power. Very many oil-globules are also seen, which lie evenly in contact with the sides and floor of the duct: it is difficult to determine whether these have escaped from their cells or not: it seems probable, however, that they are for the most part free, having recently been liberated by the solution of their cell wall. The margin of a lobule, in the condition now described, presents no trace of basement membrane; the cells themselves form the wall of the ducts, preserving still the general outline: it seems, therefore, certain that the basement membrane is only a temporary structure, which disappears when the cells are actively discharging their contents. A forcible and instructive contrast to the above condition was exhibited by a liver which I examined, which was in an advanced state of fatty degeneration: in this the linear arrangement of the cells was lost; they lay confusedly together; and were gorged with their fatty contents; the margin of the lobule, far from exhibiting any tendency to discharge the retained secretion, was invested, and, as it were, closely bound by a membrane, not of the delicate transparent texture of the basement tissue, but much more opake, and closely resembling the semi-fibrous aspect of thin layers of false membrane."

With respect to the dissolution of the membrane surrounding the lobules at the period of the most active secretion of the bile, it may be remarked that it is a matter of very great question whether this is either a constant and necessary occurrence, or even a very frequent one.

Gall Bladder. — The gall bladder is composed of an outer, strong, fibrous tunic, and an inner mucous one: this latter has a honeycomb arrangement, and is of the follicular type: the larger meshes, which are plainly visible to the unaided sight, are divided by ridges of membrane into four or five other spaces or depressions of irregular size and form, also discernible without glasses; and these again are still further subdivided into other cells very numerous, and which are only to be seen with the aid of the microscope. It is these last which constitute the follicles of the mucous membrane of the gall-bladder, which differ, however, greatly from the ordinary tubular follicles of compound mucous membranes, being simple cells or depressions formed by the plaited and ridged arrangement of the membrane of the gall-bladder. The follicles in the hepatic duct, and also in the inner tunic of the vesiculæ seminales, would appear to be of the same character.

If air be inserted, by means of the blow-pipe, beneath the mucous coat, the latter will be thrown up into lobes, each of which corresponds with one of the larger honeycomb cells: this fact shows that the mucous membrane of the gall-bladder is bound down to the fibrous tissue beneath, principally in the intervals between the cellular depressions alluded to.

Injection thrown into the ductus communis choledochus very frequently reaches the coats of the gall-bladder: this fact affords an interesting and striking proof that the vessels ordinarily injected from the common hepatic duct are not biliary, for it is generally acknowledged that biliary ducts do not exist in this situation, — a conclusion to which one, without hesitation, arrives, on reflecting that in such a situation they could serve no possible purpose.

General Remarks. — Should the foregoing account of the mode of termination of the biliary ducts be correct, of which scarcely a reasonable doubt can be entertained, it is evident that in the vertebrate class of animals, at least, the liver is not of the follicular type, and that in them this organ should be separated from those glands formed on the follicular type. In the fact of the secretion making its way into closed vessels, the liver clearly manifests an intimate and essential relationship with the vascular glands.

The liver, then, in the vertebrate series, is the only exception, with which we are at present acquainted, of an organ which, being furnished with an excretory duct, is yet not formed on the follicular plan of development.

In all follicular glands, the secreting cells are situated on the internal surface of the basement membrane: in the liver, however, they are placed upon its external surface, the true basement membrane terminating with the termination of the biliary vessels.

Mr. Bowman regards the innumerable series of secreting cells as representing the continuation of the biliary ducts, and a rudimentary condition of which he considers them to be; in the same manner as linear series of granular cells represent, according to some observers, the rudimentary form of other vessels and tissues; as, for example, the muscular fibre and the primitive nerve tubule.

Vascular Apparatus.

The vascular apparatus of the liver has been well understood since the period of the publication of Mr. Kiernan's Researches. This apparatus consists of hepatic veins, portal vein, and hepatic artery.

Hepatic Veins.—The venæ cavæ hepaticæ commence in the centre of each lobule of the liver by a plexus of capillaries, which penetrates it in all directions; these uniting, form larger vessels, and which, again, join together, to constitute the *central lobular* vein: this escaping from the lobule altogether, becomes what has been termed the *sublobular* vein, and it next unites with other sublobular veins to form the main branches of the hepatic veins. (Plate LV. *fig.* 1, 2.)

Portal Veins.—The portal vein is mainly formed by the union of the inferior and superior mesenteric veins; and these, again, have their origin principally in the confluence of the capillary vessels of the villi of the small intestines.

The portal vein enters the substance of the liver at the transverse fissure. After numerous ramifications, many of its branches are spread over the outer surface of the lobules: these branches are called the *interlobular* veins: from these branches others still smaller proceed; these, penetrating the substance of the lobules, break up into capillaries, which unite with the capillaries of the lobular hepatic veins, already spoken of; and it is the capillaries of both hepatic and portal veins, thus united, that constitute the *lobular capillary plexus.* (Plate LV. *fig.* 4.; Plate LVI. *fig.* 1.)

The lobular plexus may be completely injected either from the portal or hepatic veins, as might be supposed from the fact of its being constituted of vessels derived from both. This plexus, however, is not always fully injected: it is only when the operation of injection has been very successfully performed that this result is secured: sometimes, in injecting from the portal vein, the injection fills only those vessels which ramify on the surface of the lobules, viz. the interlobular veins, as represented in Plate LV. *fig.* 4.; in other instances, the injection will penetrate further, and fill that portion of the lobular plexus which is formed by the capillaries which belong especially to the portal vein; in this case a zone of capillaries surrounds each lobule, as figured in Plate LVI. *fig.* 1. In others, again, the injection will fill the entire lobular plexus, and extend even to the central lobular hepatic vein (Plate LVI. *fig.* 4); in this latter case, the entire section of the liver appears but a mass of capillaries, the size and form of the lobules being indicated merely by the cut extremities of the larger lobular and interlobular vessels.

On the other hand, in injecting from the hepatic veins, the injection may reach only the central lobular vein and its principal ramifications, as shown in Plate LV. *fig.* 1.; or it may fill that portion of the lobular plexus especially formed by the capillaries of the hepatic veins, in which case each lobule will appear to be the centre of a separate injection (Plate LV. *fig.* 2.); lastly, the entire lobular capillary plexus is sometimes injected from the hepatic veins in the same manner as from the portal vein.

In those instances in which two lobules are seen to be united together, the vessels are also observed to proceed directly from one to the other; this communication is especially evident in injections of the hepatic veins. (Plate LV. *fig.* 2.)

The form of the portal vein, from its origin in the villi of the intestines to its termination in the lobules of the liver, may then be compared either to two trees joined by their trunks, or to a single uprooted tree. The preceding account renders it evident that it is from the blood contained in the portal vein that the secretion of bile takes place.

In those cases in which the blood-vessels become injected from the biliary ducts, it is usually the portal system which receives the greater part of the injection; and this is thrown into it at different points irregularly, so that there are no definite zones of capillaries marking out the lobules; but masses of capillaries are seen here and there arranged without any certain order.

Hepatic Artery. — The hepatic artery is the nutritious vessel of the liver; it supplies the vessels of the hepatic ducts, the vasa vasorum, and the capsule of the liver.

It is distributed principally, however, to the capsules covering the lobules, and to the general capsular investment of the liver.

Some of the interlobular or lesser capsular branches penetrate the substance of the lobules, and terminate in the portal capillaries of the lobular plexus. (See Plate LVI. *fig.* 2.)

The outer capsular branches are remarkable for their great length, and the simple manner in which they divide and subdivide.

The hepatic artery does not anastomose with the hepatic vein.

Pathology.

The pathology of the liver may be divided into two sections, according as the seat of the disease affects its secreting or vascular apparatus.

Secreting Apparatus.

Two abnormal conditions of the secreting cells of the liver have been noticed: in the first, biliary engorgement, the cells are seen to contain a greater quantity of biliary matter, in the form of globules of various sizes, than ordinary; in the second, fatty degeneration of the liver, the cells are laden with innumerable globules of an oleaginous character; this condition of the cells, of course, impairs, to a very great extent, their secretory powers. (See Plate LVII. *fig.* 2.)

Livers thus laden with oleaginous particles have been termed fatty; this term, although expressive, is certainly incorrect. Fat is a distinctly organised cellular constituent of the higher forms of animal organisation; and each true fat globule is a perfect cell, constituted of nucleus and cell wall. The minute globules of oil existing in the cells of the liver and of some other glands, especially in disease, have none of the attributes of cells; they are merely globular collections of an oily fluid, similar to those which exist in the cells of cartilages.

It is, therefore, evident that the term fatty applied to organs affected in the manner described, is scientifically and fundamentally improper: the appellation of oily would be more correct.

The truly fatty liver and kidney do, certainly, occasionally present themselves to our notice; in these, there is an accumulation of true fat cells, not, indeed, within the epithelial particles, but in the interspaces between the lobules and tubules, and also beneath the capsules to a less degree.

The microscopic characters of the disease called cirrhosis do not appear to have been as yet satisfactorily determined.

Vascular Apparatus.

A knowledge of the distribution of the blood-vessels in the lobules of the liver, has enabled the Pathologist to explain satisfactorily various abnormal appearances connected with its vascular apparatus.

The lobules of the liver of persons or animals that have bled to death, or that have died in an exceedingly anæmic condition resulting from disease, present a pale and exsanguine appearance, arising from the small quantity of blood contained within the blood-vessels.

A second very common appearance of the lobules of the liver, after death, is that in which they are red in the centre and pale around the margin. This condition arises from the presence, in the venous hepatic vessels, of a considerable quantity of blood, the portal vessels being at the same time almost destitute of this fluid; it has been called by Mr. Kiernan the *first* stage of *hepatic venous* congestion, and is said to be due to the continuance of capillary action in the vessels after the general circulation has ceased.

In the *second* stage of hepatic venous congestion, not merely the centres of the lobules are red, but also the portal plexus in parts; the parts of the lobules which are most free from congestion are those surrounding the interlobular spaces; so that the non-congested portions appear in the form of isolated and irregular patches, in the midst of which are situated the interlobular fissures and spaces. The second stage of hepatic venous congestion commonly attends disease of the heart and other disorders in which there is an impediment to the venous circulation, and it also gives rise, in combination with accumulation of bile in the secreting cells, to those various appearances which characterise the *nutmeg* or dram-drinker's liver.

A third form of venous congestion is that which affects the portal veins alone; in this the margins of the lobules are red, while their centres are pale; it is the very reverse condition to hepatic venous congestion in its first stage, and has been distinguished by Mr. Kiernan, by the name of *portal venous congestion*. This form of congestion is rare, and has hitherto been noticed to occur in children only.

The fluid of the liver, the bile, has already been described in this work; in addition to the epithelial scales derived from the mucous membrane lining the gall-bladder, the bile frequently contains, when inspissated, concrete masses of biliary matter, which have been mistaken for true cells, also crystals of cholesterine, gall-stones, and the parasite called the fluke with its ova.

Hydatids are frequently developed in the substance of the liver; these often attain a very large size.*

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* On one occasion I noticed the liver to be thickly studded throughout with numerous cysts, the largest of about the twelfth or eighth of an inch in diameter. These cysts contained a gaseous fluid only; the secreting cells included a greater quantity of oil than natural.

Development of the Liver.

"With respect to the development of the liver, the author* considers the opinion of Reichart to be decidedly the correct one, namely, that its formation commences by a cellular growth from the germinal membrane, independently of any protrusion of the intestinal canal. On the morning of the fifth day, the œsophagus and stomach are clearly discernible, the liver lying between the heart which is in the front, and the stomach which is behind; it is manifestly a parenchymal mass, and its border is quite distinct and separate from the digestive canal at this period; the vitelline duct is wide, it does not open into the abdominal cavity, but its canal is continued into an anterior and posterior division, which are tubes of homogeneous membrane, filled, like the duct, with opaque oily contents; the anterior one runs forwards, and forms behind the liver a terminal expanded cavity, from which then passes one offset, which gradually dilating opens into the stomach; a second, which runs in a direction upwards and backwards, and forms apparently a cæcal prolongation; and a third and fourth, which are of smaller size, arise from the anterior part of the cavity and run to the liver, though they cannot be seen to ramify in its substance; at a somewhat later period, these offsets waste away, excepting the one which is continued into the stomach, and then the mass of the liver is completely free and unconnected with any part of the intestine. As the vitelline duct contracts, the anterior and posterior prolongations of it become fairly continuous and form a loop of intestine, the posterior division being evidently destined to form the cloaca and lower part of the canal. The final development of the hepatic duct takes place about the ninth day, by a growth proceeding from the liver itself, and consisting of exactly similar material; this growth extends towards the lower part of the loop of the duodenum, which is now distinct, and appears to blend with the coats of the intestine; around it, at its lower part, the structure of the pancreas is seen to be in process of formation. The further process of development of the hepatic duct will, the author thinks, require to be carefully examined; but the details he has given in this paper have satisfied him of the correctness of the statement that the structure of the liver is essentially parenchymal."

PROSTATE GLAND.

This gland belongs to the compound follicular division, and not to the lobular class of glands; its structure consisting of clusters of follicles, united by ducts: these follicles are usually of an oval form, of large size, and frequently communicate with each other.

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* Dr. Hanfield Jones, Abstract of Paper in Philosophical Magazine, September, 1847.

The follicles cannot be exhibited separately as such, being mere excavations or cells which exist in the substance of the gland, and which are lined by prolongations of the mucous membrane of the urethra.

That the follicles constituting the essential structure of the prostate gland are simply inversions of the genito-urinary membrane, is proved by the fact that the epithelium which lines them is of the clavate form, which has been elsewhere described as appertaining to the bladder.

In consequence of the large size of the follicles, and of the fact of the epithelium which lines them forming on their interior but a single and even layer of cells, a considerable space or cavity exists in the centre of each follicle.

The tissue out of which the follicles are formed, and to the presence of which the prostate owes much of its size and nearly all its firmness, is a good example of the nucleated variety of fibro-elastic tissue, approaching in its characters very closely to the muscular fibre of organic life.

The increase which so generally takes place in the size of the prostate in old age is due to an increased development of the above-named tissue.

From the preceding description, it would appear that the office of the prostate is simply to secrete mucus, and that it does not, as has been conjectured, furnish any peculiar secretion necessary, as some even have supposed, to fecundity.

The most curious circumstance about the prostate is the almost constant occurrence, in considerable numbers, of concretions or calculi formed of concentric lamellæ. These calculi are situated in the follicles already described; they differ from each other very greatly in size, form, and colour, and in the number, arrangement, and strength of the concentric capsules. Ordinarily, the concentric lamellæ are disposed around a single nucleus of granular and amorphous matter; sometimes, however, there are two or even three separate nuclei within each calculus; in these cases, each nucleus will be encircled by its own lamellæ, the entire of them being also included in a greater or less number of larger lamellæ. The form of the calculi, although various, has a tendency to the triangular; and the colour, although differing in different glands, depends upon their size and age, the younger and smaller being transparent and almost free from colour, the older and larger being of a deep orange or ochre tint. (Plate LVII. *fig*. 3.)

The prostatic calculi have been noticed by several observers; by Cruveilhier, Dr. Jones, Mr. Quekett, Mr. Adams, of the London Hospital, Dr. Letheby, and myself.

Dr. Jones* describes them as originating in oval or rounded nucleated and organic vesicles, which enlarge and then have their amorphous contents arranged into concentric laminæ. Dr. Letheby believes that "they are concretions which arise exactly like those of the kidney and bladder, viz., by a succession of external deposits;" this view is most probably the correct one.

Dr. Letheby has favoured me with the following observations on the chemistry of these bodies: "You will find," he says †, "that they consist of phosphate of lime, which is mixed up with a large quantity of nucleated fat cells and inspissated mucus; the whole being generally tinted with some shade of yellow or red."

"They are slowly soluble in strong acetic and muriatic acids; more quickly when heated, and they then leave numerous fat globules and remnants of cells. They are not dissolved by potash or strong ammonia. Heated before the blow-pipe, they char and leave a small residue of earthy matter."

The smaller calculi resemble closely the concentric corpuscles or bodies described by Mr. Gulliver as occurring in fibrinous clots, and many of them do not present concentric lamellæ.

TUBULAR GLANDS.

SUDORIFEROUS GLANDS.

The sudoriferous are the most numerous class of glands in the body, their apertures thickly studding the entire external surface, and far outnumbering the sebaceous glands, which have a somewhat similar distribution.

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* Medical Gazette, 1847.

† In litt.

They consist of convoluted tubes of nearly equal diameter, which unite, at irregular intervals, with each other, forming looped meshes, all of which terminate in a single excretory duct. (See Plate LVII. *fig.* 4.)

The excretory duct is either straight or coiled spirally, and it always terminates in a raised and rounded mammillary process, evident on the surface of the epidermis. (See Plate XXIII. *fig.* 1.) It is straight where the epidermis which it has to pass through is thin, and where, in consequence, its course to the surface is short; on the other hand, it is coiled in spires which are remarkable for their extreme regularity, where this membrane is thick, as in the palms of the hands and soles of the feet (see Plate XXIV. *fig.* 3.), and where as a result its course is prolonged. The acting cause which determines this spiral arrangement is probably the gradual flattening to which the outer and older layers of epidermic cells are continually subject from pressure.

The duct of the sudoriferous glands is formed by an inversion of the epidermis itself, similar to that which forms the lining of the hair follicles. The sudoriferous glands never open into the hair follicles, but in the intervals between them and also between the sensory papillæ with which the true skin is covered.

The palms of the hands and soles of the feet, being entirely free from the sebaceous glands, are occupied exclusively with the sudoriferous; they are placed in lines or rows, which are variously curved, and which correspond with the arrangement of the sensory papillæ of the true skin. The apertures of the sudoriferous glands on the ridges of the skin are just perceptible with the naked eye, but they become very evident and conspicuous with a lens of moderate power. (Plate XXIV. *fig.* 1.)

The secreting cells of the sudoriferous glands are small.

The tubes are formed like those of the testes of a nucleated variety of fibro-elastic tissue, and are surrounded by a similar plexus of capillaries. These vessels, as well as the tubes themselves, are held in position by bands of fibrous tissue.

The following calculations by Mr. Wilson will serve to convey some idea of the extent and importance of the sudoriferous system: —

> "To arrive at something like an estimate of the value of the perspiratory system in relation to the rest of the organism, I counted the perspiratory pores on the palm of the hand, and found 3528 in a square inch. Now, each of these pores being the aperture of a little tube of about a quarter of an inch long, it follows, that, in a square inch of skin on the palm of the hand, there exists a length of tube equal to 882 inches, or 73½ feet. On the pulps of the fingers, where the ridges of the sensitive layer of the true skin are somewhat finer than in the palm of the hand, the number of pores on a square inch a little exceed that of the palm; and on the heel, where the ridges are coarser, the number of pores on the square inch is 2268, and the length of the tube, 567 inches, or 47 feet. To obtain an estimate of the length of tube of the perspiratory system of the whole surface of the body, I think that 2800 might be taken as a fair average of the number of pores in the square inch; and 700, consequently, of the number of inches in length. Now, the number of square inches of surface in a man of ordinary height and bulk is 2500; the number of pores, therefore, 7,000,000; and the number of inches of perspiratory tube, 1,750,000, that is 145,833 feet, or 48,600 yards, or nearly twenty-eight miles."*

AXILLARY GLANDS.

These glands, first described by Professor Horner and M. Robin, are probably but a variety of the ordinary sudoriferous glands.

They are situated in the axillæ, are similar in organisation to the sudoriferous glands, but are much larger than these.

They doubtless furnish the peculiar and odorous secretion, which characterises the region of the axillæ.

This odorous principle, it is said, exists in the blood ready formed, and the glandulæ merely separate it from that fluid. It is also stated that its presence may be detected, in dried blood, on the addition of sulphuric acid, and that its odour is different in the male and female, also that even the blood of different animals may be distinguished by means of it; assertions which are very doubtful.†

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* Diseases of the Skin, p. 18.

† Annales d'Hygiène, vol. i. ii. x. &c.

CERUMINOUS GLANDS.

The ceruminous glands are situated beneath the integument of the deeper part of the external meatus of the ear. They occur mixed up with numerous sebaceous glands, but have no direct communication with these, as they open on the surface by distinct apertures.

They resemble very closely in structure the sudoriferous glands just described, consisting, like them, of convoluted and looped tubes, which unite together and end in a single slender duct. They differ, however, from the sudoriferous glands in the fragile character of the tubes, which renders it somewhat difficult to procure a perfect preparation of one of them; this difference seems to arise principally from the absence, in a great measure, of fibrous tissue, whereby, in the sudoriferous glands, the tubes are bound together, as well as of also enveloping plexuses of blood-vessels. (See Plate LVII. *fig.* 5.)

In the external ear of the sheep, in which these glands may be studied to great advantage, the tubes appear of a pale straw colour, transparent and glossy, with but few apparent granular cells, and these totally different from the characteristic cells of the sebaceous glands, filled with innumerable globules of oil. The granular cells filling the tubes, and which are usually concealed by a quantity of oily fluid, may be made apparent by the addition of acetic acid. The membrane of the tubes is composed of a nucleated form of elastic tissue.*

From the fact of the ceruminous glands coexisting with numerous sebaceous glands, it seems probable that the cerumen is the mixed production of the two descriptions of glands.

KIDNEYS.

The substance of the kidney, like that of the other large glands, may be divided, for the purposes of description, into two orders or systems of structure or apparatus: the glandular or secretory, which is the most important and characteristic; and the vascular, which is but subordinate.

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* It seems doubtful, after all, whether the ceruminous are any thing more than a variety of the sudoriferous glands.

Secreting Apparatus.

The secreting apparatus of the kidney consists of the tubes; their enlarged and globular extremities, which, in part, constitute those peculiar and interesting structures, the Malpighian bodies, and their contained granular cells. (See Plate LVIII. *figs.* 1. 6., Plate LX. *figs.* 2, 3.)

Tubes.—The substance of the kidney is divided into an outer cortical and an inner or medullary part. The former is generally conceived to be the secreting portion of the kidney, and the latter merely the tubular or conducting portion through which the urine passes in its way to the ureter. This notion of the nature of the two parts and of their mutual relation is certainly erroneous, as is proved by the facts that both portions of the kidney are alike formed of tubes, and that all these tubes are abundantly furnished with secreting cells.

The secreting structure of the *cortical* part of the kidney is distinguished by the large size of its tubes; their tortuous course; the loops formed by them, not merely on the surface of the kidney, but also in its interior; by the globular enlargements in which they terminate; and by the larger size &c. of their contained cells.

The *medullary* part of the kidney is characterised by the smaller calibre of its tubes, their straight course, the absence of dilated extremities, and the frequency of the union of the tubes with each other.

The tubes then of the kidney, describing their course from without inwards, commence in dilated extremities (see Plate LX. *figs.* 2, 3.), which form part of the structure of the Malpighian bodies; they afterwards take a tortuous course, describing loops on the surface of the organ, as well as in its interior (see Plate LIX. *fig.* 2. and Plate LVIII. *fig.* 1.), until they reach the medullary part, when their course becomes straight, and where they frequently unite, especially near its lower portion, in a dichotomous manner, thus forming a number of larger tubes, which terminate in the mammillary processes which dip into the midst of the chambers called chalices.

According to the above description of the course and origin of the tubes of the kidney, which is now the generally received one, each tube commences in a single dilated extremity; it seems to me, however, to be probable that many of the tubes have their origin in loops; the fact of the occurrence of loops throughout both the medullary and the cortical parts of the kidney, the universal formation of loops on the surface of that organ, and the non-existence of dilated extremities of tubes on that surface, all tend to prove the correctness of the view just mentioned.

The tubes of the kidney, wherever encountered, consist of a strong and structureless basement membrane (see Plate LVIII. *fig.* 1.); it is worthy, however, of especial notice that these tubes, as well as their globular terminations, are all inclosed in a framework constituted of a nucleated form of elastic tissue. This framework is seen to most advantage in cross-sections; this it is which keeps the tubes distinct from each other, and which explains the occurrence of intervals between the tubes, seen especially in longitudinal sections. (See Plate LVIII. *fig.* 2.)

Malpighian Dilatations.—It is certain that some, if not all, of the tubes terminate in enlarged extremities. These dilatations constitute the Malpighian bodies in part only; they are of a globular form, and their diameter exceeds five or six times that of the tube itself. (See Plate LX. *figs.* 2, 3.) They vary, however, considerably in size, in all parts of the cortical substance of the kidney; and Mr. Bowman states that they are largest near to the point of junction between the cortical and medullary portions.

The best way to obtain a satisfactory view of these bodies is to tear up with needles a fragment of the cortical substance of the kidney, and to search amongst the divided shreds for the Malpighian dilatations which are there met with in all possible conditions. Some will be seen entirely detached, lying loose in the water in which the fragment has been torn up, others will be observed to be attached to the tubes which take their origin from them. All of these, however, whether attached or loose, will occur in one of two states; either the surface of each will be seen to be constituted of convoluted and branched tubes, the vessels of the Malpighian plexus; or it will appear perfectly smooth and even. The former condition is the more frequent; the latter is by far the less common, and is explained by the fact that in this case the Malpighian dilatation is inclosed in a capsule of fibro-elastic tissue of considerable thickness, a continuation of that which invests the tubes themselves. (See Plate LX. *figs.* 2, 3, and Plate LVIII. *fig.* 2.)

The Malpighian dilatations rarely, if ever, extend to the surface of the kidney; they have been, in all the instances in which they have been noticed by the Author, covered by convolutions of the tubes.

Epithelium.—The epithelium of the kidney presents several well-marked modifications, in different localities of that organ.

The epithelium of the tubes of the cortical part of the kidney, save within a short distance of their junction with the Malpighian dilatations, is composed of large and angular scales or cells, which are coarsely granular, and which form a regular layer of pavement epithelium lining the tubes; the centres of these are unoccupied with cells, and are thus left pervious for the passage of the urine. (See Plate LVIII. *fig.* 6.)

The cells forming the epithelium of the tubes of the medullary part of the kidney are of much smaller size than those contained in the tubes of its cortical substance, consisting of nuclei, surrounded by a very narrow border. (See Plate LVIII. *fig.* 6.)

The cells situated at the neck of the Malpighian dilatations are of the ciliated kind: these were first noticed by Mr. Bowman in the kidney of the frog, and that gentleman conjectured their existence in the higher animals; the Author has seen them in action in the sheep, rabbit, and horse. (See Plate LX. *fig.* 3.)

Lastly, the cells which invariably line the Malpighian dilatations of the tubes are small and furnished with oval nuclei. (See Plate LX. *fig.* 3.) Mr. Bowman considered that epithelium was not constantly present in these bodies; and that, when it was so, it only lined that portion of them in connection with the tubes. This statement arose in a misapprehension of the real structure of the Malpighian body.

Vascular Apparatus.

The vessels of the kidney consist of the renal artery and vein, also of a vein which may be called portal: we will first trace the course of the artery.

Renal Artery.—The renal artery, after its entrance into the substance of the kidney, divides into numerous branches, some of them pass between the medullary cones, others traverse these in sets: arrived at the cortical part of the kidney, many undergo a further subdivision, and some, passing towards the Malpighian dilatations, form in part, upon its external surface, the Malpighian tuft or plexus of vessels (see Plate LIX. *figs.* 1. 5.); others continue onwards to the surface of the kidney, and there terminate in capillaries. (See Plate LIX. *fig.* 2.) Such is a brief sketch of the course of the renal artery.

The branches of the renal artery take, through the cortical part of the kidney, a straight and parallel course; some of these branches give off lesser vessels on each side, which pass towards, and are expended upon the Malpighian dilatations, as also is, ultimately, the terminations of the main vessels from which the lesser ones proceeded. Others, again, of the larger and parallel branches, in like manner give off Malpighian twigs; but their terminations, in place of being exhausted upon the Malpighian dilatations, reach the surface, and there form, with the branches of the renal vein, an *interlobular* plexus. It is seldom that a branch of the artery reaches the surface of the kidney, without first communicating with the Malpighian dilatations.

Renal Vein.—The renal vein has two origins: one in the capillaries on the surface of the kidney; these capillaries, uniting with those of the renal artery, form the plexus, which ramifies in the interstices left between the terminal loops of the tubes (see Plate LIX. *fig.* 2.): the second origin is in the plexus of capillaries surrounding the tubes formed by the junction of the capillaries of both artery and vein; from these two origins and plexuses branches proceed; these, uniting with each other, form larger vessels, which also pass through the medullary part of the kidney in sets. (See Plate LVIII. *figs.* 4, 5.)

Portal Vein.—Each Malpighian tuft or plexus of vessels is formed, like other plexuses, of capillaries derived in part from an artery and in part from a vein. As a single arterial twig proceeds to each Malpighian dilatation — the *afferent* vessel, so a single venous twig departs from it — the *efferent* vessel; this vessel is usually of much smaller size than the artery, and terminates in the capillaries which encircle the uriniferous tubes. (See Plate LX. *fig.* 2.)

The efferent vessel of the Malpighian tuft resembles in its origin and distribution the portal vessel of the liver, being in connection with capillaries, at both its origin and its termination: in consequence of this resemblance it has been termed by Mr. Bowman the portal vein of the kidney; and as each Malpighian plexus has a separate efferent vessel, to the aggregate of these that gentleman applies the term "*portal system*" of the kidney.

The above description of the vascular distribution belonging to the kidney differs, in some important respects, from that given by Mr. Bowman, as we shall now proceed to make apparent.

In the first place, Mr. Bowman describes the afferent vessel of the Malpighian tuft as piercing the membrane of the enlarged extremity of the tube, and as forming within this, by its numerous subdivisions, the Malpighian plexus: the efferent vessel, in like manner, perforating the membrane of the dilatation, or proper capsule.

This view of the position of the Malpighian plexus is undoubtedly incorrect; this plexus, like every other plexus belonging to glands formed on the tubular or follicular types, is situated on the external surface of the basement membrane, that is, embracing the globular head of the tubes, and lying between this and the framework of elastic tissue already described. Analogy, therefore, is entirely opposed to the description of the author of the paper in the Philosophical Transactions to which reference has been made more than once.

In the second place, Mr. Bowman describes the renal artery as being spent upon the Malpighian bodies, with the exception of a few branches given off to the coats of the excretory ducts and of the larger vessels; while, according to the Author's observations, only a proportion of the branches of the renal artery are thus disposed of.

The accuracy of the foregoing account of the distribution of the blood-vessels of the kidney is borne out, to a very great extent, by the results furnished by injection.

1st. The Malpighian plexus can be injected with great facility by the artery, but not by the vein: the reason of this will be obvious on a little reflection; the branches of the renal artery pass directly to the Malpighian plexus; those of the renal vein, commencing from the larger or terminal trunks, end either in the plexus surrounding the tubes of the kidney, or in that which lies on its surface between the convolutions of those tubes; and it is in one or other plexus that the efferent or portal vein of the Malpighian tuft terminates; so that between the terminal branches of the renal vein and the origin of the efferent vessel, a complicated plexus is interposed — that surrounding the uriniferous tubes; the injection, therefore, before reaching the Malpighian tuft, would have to traverse the plexus already spoken of; and it is this which accounts for its being so difficult, if not impossible, to inject the Malpighian plexus from the renal vein.

2nd. The plexus surrounding the tubes may be injected with care, from both the artery and vein; but especially from the latter.

3rd. The plexus, ramifying between the loops of the tubes on the surface of the kidney, may also be readily injected from either artery or vein.

Occasionally, the injection will pass from the blood-vessels, and escape into the tubes, or their Malpighian extremities.

The tubes themselves, and very rarely their globular terminations, may be injected from the ureter: this is accomplished more readily in the kidneys of some animals, as the horse, than in those of man.

A complete Malpighian body, then, consists of the globular enlargement of the tube, over which is spread the Malpighian plexus, formed by branches of the renal artery and portal vein; this plexus does not consist entirely of capillary meshes, but of vessels of different diameters; the artery divides and subdivides: its terminal branches are, however, capillary in size, but, in place of forming distinct meshes, follow a serpentine and convoluted course. (See Plate LX. *fig.* 2.)

Mr. Bowman conceived, as already noticed, that the Malpighian plexus was situated *within* the globular enlargement of the uriniferous tube; and, reflecting on the remarkable structure of the Malpighian bodies, and on their singular connection with the tubes, was led to consider that the tubes and their plexus of capillaries are the parts concerned in the secretion of that portion of the urine to which its characteristic properties are due (the urea, lithic acid, &c.), while the Malpighian bodies are an apparatus destined to separate from the blood the watery portion of the urine.

"It would indeed be difficult," Mr. Bowman writes, "to conceive a disposition of parts more calculated to favour the escape of water from the blood than that of the Malpighian body. A large artery breaks up, in a very direct manner, into a number of minute branches, each of which suddenly opens into an assemblage of vessels of far greater aggregate capacity than itself, and from which there is but one narrow exit. Hence must arise a very abrupt retardation of the velocity of the current of blood. The vessels in which this delay occurs are uncovered by any structure. They lie bare in a cell from which there is but one outlet, the orifice of the tube. This orifice is encircled by cilia, in active motion, directing a current towards the tube. These exquisite organs must not only serve to carry forward the fluid already in the cell, and in which the vascular tuft is bathed, but must tend to remove pressure from the free surface of the vessels, and so to encourage the escape of their more fluid contents. Why is so wonderful an apparatus placed at the extremity of each uriniferous tube, if not to furnish water, to aid in the separation and solution of the urinous products from the epithelium of the tube?" P. 75.

My view of the nature of the Malpighian body differs, in some respects, from that entertained by Mr. Bowman. The proper Malpighian capsule is invariably lined by innumerable granular cells; for this single and simple reason, therefore, I regard this body as a secreting organ as much as the uriniferous tubes themselves, which present an organisation essentially the same. I differ, therefore, from Mr. Bowman, who considers the epithelium of the tubes as the sole true secreting agents of the urine. I conceive that this fluid is formed in every part of the tubular and Malpighian surface of the kidney, and I dissent from the opinion that the Malpighian body is an apparatus destined for the simple separation of the watery parts of the urine apart from any act of secretion.

Nevertheless, I so far agree with Mr. Bowman in his theory, as to consider that the greater portion of the more watery parts of the urine proceed from the Malpighian bodies; not, however, by an act of simple separation, but by one of secretion. The peculiar arrangement of the blood-vessels, and the presence of ciliated epithelium at the entrance to the tubes, are facts in themselves sufficiently conclusive of the accuracy of this view: as, on the other hand, I conceive the great extent of secreting surface presented by the tubes to be in itself sufficient to prove that at least a portion of the aqueous constituent of the urine emanates from this surface.

An accurate knowledge of the pathology of the kidney and urine would, doubtless, furnish arguments conclusive as to the relative functions and importance of the tubes, and their enveloping plexus and the Malpighian bodies.

The reader will at once observe that one of the arguments in favour of Mr. Bowman's theory, urged in the preceding exposition, does not hold good, in consequence of its want of accordance with the true structure. I allude to the supposed entrance of the plexus into the cavity of the proper Malpighian capsule.

In birds and reptiles, the Malpighian plexus is not formed of a number of convoluted vessels, resulting from the repeated subdivision of the afferent artery, as is the case in all the Mammalia, but simply consists of a single coiled vessel, so that the afferent and the efferent vessels of each tuft are one and the same by direct continuity. In these classes, the efferent vessel readily admits of being injected from the artery, and this in consequence of the simplicity of the plexus surrounding the Malpighian enlargement.

The size of the Malpighian bodies varies, not merely in the same kidney, but also to a still greater extent in the kidneys of different animals: they are largest in the elephant and horse, and smallest in birds.

Development of the Kidney.

According to Dr. Carpenter, " The first appearance of any thing resembling a urinary apparatus in the chick, is seen in the second half of the third day. The form at the time presented by it is that of a long canal, extending on each side of the spinal column, from the region of the heart towards the allantois; and the sides of these present elevations and depressions, indicative of the commencing development of cœca.

" On the fourth day, the *Corpora Wolffiana*, as they are termed, are distinctly recognised, as composed of a series of cæcal appendages, which are attached along the whole course of the first-mentioned canal, opening into its outer side. On the fifth day, these appendages are convoluted; and the body which they form acquires increased breadth and thickness. They evidently then possess a secreting function; and the fluid which they separate is poured by the long straight canal into the cloaca. Between their component shut sacs numbers of small points appear, which consist of little clusters of convoluted vessels exactly analogous to the Corpora Malpighiana of the kidney. The Corpora Wolffiana, however, have only a temporary existence in the higher Vertebrata, although it seems that in fishes they constitute the permanent kidney. The development of the true kidneys commences in the chick about the fifth day. They are seen, on the sixth, as lobulated greyish masses, which sprout from the outer edges of the Wolffian bodies; and they gradually increase, the temporary organs diminishing in the same proportion. The sexual organs, as will be hereafter explained, also originate in the Wolffian bodies; and at the end of fœtal life, the only vestige of the latter is to be found as a shrunk rudiment situated near the testes of the male. The progress of development in the human embryo seems closely conformable to the foregoing account. The Wolffian bodies begin to appear towards the end of the first month; and it is in the course of the seventh week that the true kidneys first present themselves. From the beginning of the third month, the diminution in the size of the Wolffian bodies goes on pari passu with the increase of the kidneys; and at the time of birth, scarcely any traces of them can be found. At the end of the third month, the kidneys consist of seven or eight lobules, the future pyramids; their secreting ducts still terminate in the same canal, which receives those of the Wolffian bodies and of the sexual organs. And this opens with the rectum into a sort of cloaca, or sinus urogenitalis, analogous to that which is permanent in the oviparous Vertebrata. The kidneys are at this time covered by the supra-renal capsules, which are very large; about the sixth month, however, these have decreased, whilst the kidneys have increased, so that their proportional weight is as 1 to 4½. At birth, the weight of the kidney is about three times that of the supra-renal capsules, and they bear to the whole body the proportion of 1 to 80; in the adult, however, they are no more than 1 to 240. The Corpora Wolffiana are, when at their greatest development, the most vascular parts of the body next to the liver; four or five branches from the aorta are distributed to each, and two veins are returned from each to the vena cava. The upper veins and their corresponding arteries are converted into the renal and emulgent vessels; and the lower, into the spermatic vessels. The lobulated appearance of the kidney gradually disappears; partly in consequence of the condensation of the areolar tissue, which connects the different parts; and partly through the development of additional tubuli in the interstices."

It is only necessary to observe, in addition to the description of Dr. Carpenter, that, although the development of the kidney commences near to the Wolffian body, it is yet not formed out of it, but has an independent origin in its own proper blastema or primordial matter. In its earliest condition in the Mammalia, it consists of tubes proceeding from the hilus outwards towards the circumference in bundles; these tubes afterwards separate and become contorted, yet all terminate in enlarged and vesicular extremities, — the Malpighian bodies. In the earliest state in which the kidney can be examined, the cæca alone exist in connection with short tubes; the central or proximal extremities are free, and not yet united to the ureter. This fact proves that the kidney is not an involution of the genito-urinary mucous membrane, but an independent formation, as is, probably, every other gland.

Such is a simple, concise, and, it is believed, in all essential particulars, a correct account of the normal anatomy of the kidney.

Reference to the various discrepant, contradictory, and often erroneous statements of many writers on this subject has been hitherto purposely avoided, lest such should obscure the simplicity of the description just given. A few of the more remarkable statements and opinions advanced respecting the anatomy of the renal organs may now, however, be noticed with advantage and interest.

Every statement, without exception, made by Mr. Bowman, one of the earliest and very best writers on the minute anatomy of the kidney has been from time to time contradicted by different observers; by others, again, the descriptions of that gentleman have been confirmed, and not denied. As might be readily imagined, the truth lies not exclusively with either the denying or the confirming observers.

Thus the reality of any connexion existing between the tube and the Malpighian body has been questioned and denied, and still continues to be so; as also the existence of a vibratile epithelium in the upper portion of the uriniferous tube. The first particular has been denied by Muller *, Reichert †, Gerlach and Bidder; and the second has been doubted or denied by Huschke, Reichert, and Bidder. On the other hand, the observations of Schumlansky ‡, and A. Koelliker of Zurich accord with those of Mr. Bowman on the first particular, and those of Bischoff, Valentin, Pappenheim, Gerlach, and Koelliker §, on the second, the latter observer describing the entire epithelium of the tubes as ciliated.

It is so easy, however, to satisfy ourselves, in the kidney of every animal, of the reality of a connexion between the tube and the Malpighian body, as well as of the presence of a cili-

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* De Glandularum Secernentium Structura Peinitiori, Earumque prima formatione in Homine atque Animalibus, Commentatio Anatomica. Cum Tabulis æn. incisis xvii. Leipsiæ, 1830.

† Bericht über die Fortschritte der Mikroscopischen Anatomie in dem Jahre 1842; von K. B. Reichert, Prof. in Dorpat, Müller's Archiv, 1843.

‡ De Structura Renum, 8vo. 1788.

§ Ueber Flimmerbeweg-ungen in den Primordial Nieren, Archiv für Anatomie, Physiologie, und Wissenchaftliche Medicin, Heft V. S. 518 1845.

ated epithelium, in the upper portion of the uriniferous tubes, that it would be perfectly unjustifiable for observers again to call these two points in question.

The statement of Mr. Bowman, which has met with most opposition, is that made as to the entrance of the Malpighian capillary plexus into the cavity of the true capsule. Some observers have denied the correctness of this description, on the simple ground of the anomalous position in which the blood vessels would be placed, were such an arrangement the true one. This objection, however, is insufficient to disprove the accuracy of Mr. Bowman's explanation, since in the liver there is every reason to believe that the vascular and secreting elements of glands are intimately associated. Again, some observers, not satisfied with Mr. Bowman's description, have given others.

Thus Gerlach * says that the Malpighian capsule is not, as Mr. Bowman described it, a blind termination of a uriniferous duct, but a retraction or introversion, a *diverticulum* of the same structureless membrane which forms the uriniferous tubes;— also, "that when the Malpighian capillary network is closely examined, after the capsule has been entirely detached from it, we see it in its whole extent covered by a thick layer of nucleated cells, which are continued from the inner wall of the capsule upon the Malpighian vessels; and the latter lie introverted within a layer of cells, like an intestine within the peritonæum." †

Gerlach's description is assuredly incorrect: the views of the structure of the Malpighian body, entertained by Bidder ‡, although they approach more nearly to the truth, are also inaccurate: he considers that the glomerulus, or vascular plexus, is inserted or pushed into the expanded portion of the uriniferous canal; this on its part embracing and surrounding the glomerulus. According to this view the glomerulus would still be external to the cavity of the dilated extremity of the tube, the relation between the two being comparable to the head within the double night-cap.

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* Beiträge zur Structurlehre der Niere, von Dr. Joseph Gerlach, prakt in Mainz (Mayence), Müller's Archiv, 1845.

† Edinburgh Medical and Surgical Journal, Oct. 1847.

‡ Ueber die Malpighischen Körper der Niere, von F. Bidder in Dorpat; Müller's Archiv, 1845.

The correct view of the structure of the Malpighian body is, however, much more simple than either of those just described. A Malpighian body, as already stated, consists of the dilated extremity of a uriniferous tube, over which is spread the Malpighian plexus: these two structures, viz. the dilatation of the uriniferous tube, and the vascular plexus, constitute all that is essential in the anatomy of the Malpighian body: both are inclosed in a thick capsule: this is not, however, a structure peculiar to the Malpighian body, but a mere envelope, similar to, as well as a continuation of, that which invests the tubes themselves.

A little reflection will show, that this view reconciles many of the conflicting statements, made in reference to the anatomy of the Malpighian body. The outer capsule referred to, which is that spoken of by most other observers as the true Malpighian capsule, is evidently that which Mr. Bowman had in view as the dilated extremity of the uriniferous tube, and it is this which he described as being pierced by the Malpighian artery, — a description literally and positively correct.

The common envelope, which, however, as already stated, forms no necessary part of the Malpighian body, is really pierced by both the afferent and efferent vessels of that body, as well as by the tube. (See Plate 60. *fig.* 3.) Mr. Bowman's error consists in having regarded this mere outer covering as the true dilated extremity of the uriniferous tube, which it most certainly is not, and in having necessarily, as a consequence, overlooked the true extremity of the uriniferous tube with its contained epithelium.

Again, the confounding of this common envelope with the true Malpighian capsule accounts for the assertions of those observers who state that the uriniferous tube has no connexion with that capsule: it has, indeed, no connexion by continuity; it simply pierces it: of the inner or true capsule, the uriniferous tube is absolutely a continuation.

The common envelope of the entire and perfect Malpighian body differs structurally from the true capsule; the latter is thin and structureless, the former, thick, and constituted of a delicately fibrous and nucleated form of elastic tissue.

Mr. Toynbee * is the only writer, with whose observations I am acquainted, who understands the true character of what is ordinarily regarded as the "capsule of the Corpus Malpighianum:" this he correctly describes as being a distinct globular investment, and not, as was supposed, an expansion of the tube.

Notwithstanding, however, the knowledge of this fact, Mr. Toynbee's views of the structure of the Malpighian body appear to me to be far from correct.

Thus Mr. Toynbee describes the Malpighian body as "composed of two distinct elements — a plexus of blood-vessels, and a membranous capsule, which completely surrounds and envelopes the plexus."

Each Malpighian body is indeed composed of two distinct and essential elements, the dilated extremity of the uriniferous tube embraced and surrounded by the Malpighian plexus: the outer investment, called by Mr. Toynbee and others "the capsule," is not a structure essential to the Malpighian body, since it alike invests this and the uriniferous tube for its whole length attached to it.

Again, Mr. Toynbee describes the uriniferous tube, after penetrating the capsule, as twisting into a coil, and, after being in contact with the ramifications of the corpus, as *emerging from the capsule.*

This last statement shows that Mr. Toynbee was unacquainted with the proper character of the most important and essential of the two elements of the Corpus Malpighianum, viz. the dilated extremity of the uriniferous tube, filled with its secreting cells.

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* On the Intimate Structure of the Human Kidney, and on the changes which its several parts undergo in Bright's Disease. By Joseph Toynbee, F.R.S. June, 1846. Medico Chirurgical Transactions.

Pathology.

The kidney would appear to be more liable to morbid alterations than any other organ in the body; nevertheless, its pathology is still far from being completely understood, notwithstanding that several observers have paid especial attention to the subject. Several of the pathological conditions of this organ appear to have been confounded together under the common term "Bright's Disease."

A very frequent pathological condition of the secreting cells of the kidney is that in which they are laden with globules of an oily fluid, similar to those which occur in the hepatic cells in the affection commonly called fatty liver, or fatty degeneration of the liver, but which would be more correctly distinguished by the appellation of oily liver; the corresponding affection in the renal organ being known by the name of oily kidney.

It is this condition of the renal cells which, in Dr. George Johnston's* opinion, constitutes the true Morbus Brightii.

The large, smooth, and mottled kidneys are those in which the oily matter abounds; the smoothness, according to Dr. Johnston, depending upon the uniform distribution of the tubes in the cortical portion of the kidney with the oily matter.

The wasted and granular kidneys, according to the same observer, are those in which the accumulation of fat takes place less rapidly and less uniformly; certain of the convoluted tubes becoming distended with fat, forming prominent granulations; and these, pressing upon the surrounding tubes and vessels, occasion their obliteration and atrophy, a wasting and contraction of the entire organ being the result. This condition attends the more advanced stages of Bright's Disease, and is the sequence of the first described form of the affection.

Dr. Johnston, from numerous examinations, has arrived at the interesting and important conclusion, that the oily disease of the kidney is generally co-existent with a similar affection of the liver, and even with steatomatous deposition in the coats of the arteries, and to a less extent with tubercular deposit in the lungs.

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* On the Minute Anatomy and Pathology of Bright's Disease of the Kidney, and on the relation of the Renal Disease, to those Diseases of the Liver, Heart, and Arteries with which it is commonly associated. George Johnston, M.D. Medico-chirurgical Transactions, 1846.

Dr. Johnson also maintains the opinion, that the oily deposition is not preceded by any inflammatory or congestive stage: congestion accompanies the disease; but this may be either active or passive, and when the latter, is produced by the pressure to which the vessels are subject in consequence of the distention of the epithelial cells, and which pressure gives rise to the effusion of serum and blood within the tubes. These results are, however, the effects, and not the cause of the disease.

The dropsy ensuing on scarlet fever, Dr. Johnson considers, does not depend upon the presence of oil in the cells of the kidney; this dropsy, he regards as the result partly of the cutaneous disease, and partly of the effort made by the kidneys to relieve the skin, the circulation and functions of which are so much impaired.

From experiments made on cats, it appears that confinement in dark chambers has the effect of inducing granular disease of the kidney, accompanied by deposition of oil in the urine.

Dr. Johnson regards the existence of albuminous urine as quite a secondary effect.

The results of Mr. Toynbee's investigation on the pathology of Bright's disease are very different, as we shall presently perceive, from those of Dr. Johnson: both observers, however, agree in the statement that there can be no doubt that albuminous urine often exists, without any deposition of fat in the epithelial cells of the kidney; as in dropsy after scarlatina.

The following is Mr. Toynbee's own exposition of his researches on the pathology of Bright's Disease: —

" *The First Stage of the Disease.*—In this stage the kidney is enlarged, and innumerable black points are visible, which are the corpora Malpighiana dilated, and their vessels distended with blood, seen through the capsule. The white spots which derive their appearance from the collection of fatty matter, begin to be perceptible.

"The peculiar features of this stage consist of an enlargement of the arteries entering the corpora Malpighiana; the dilatation of the vessels of the tuft, the capillaries and the veins; an increase in the size of the capsule of the corpus and of the tubuli, and a large addition to the quantity of the parenchyma of the organ.

"The condition of the arteries is visibly changed, even at this early period; the artery entering the corpus being actually twice or thrice its natural size; which is the case also with the Malpighian tuft, and the capillary vessels which spring from the tuft. An injection, in this stage, cannot very easily be made to pass through the tuft and fill the capsule of the corpus, — a circumstance which almost always attends injection in the later stages of the disease.

"The capillaries and veins are greatly enlarged, giving to the surface of the organ the resemblance of net-work. This is the commencement of the stellated condition, which is so marked a characteristic of the next stage of the complaint.

"The tubuli in this stage are also much increased in their dimensions; but the fat which is found in them is soft and white.

"*The Second Stage of the Disease.* — The organ in this stage is very greatly increased in size, its surface is smooth, and presents numerous white spots; the capsule is but slightly adherent to the surface, and the tissue of the organ is flabby.

"The structural changes exhibited during this stage are the following: —

"1st. The artery of the corpus Malpighianum becomes so greatly enlarged that frequently it equals the dimensions of the tube itself, and is eight or ten times its natural size. It is tortuous and dilated, and sometimes, previously to entering the capsule of the corpus, presents swellings analogous to those of varicose veins. The primary branches of it, in forming the tuft, are also distended to ten or fifteen times their natural size, and are not unfrequently discovered external to the capsule of the corpus, as though thrust out by some internal force. The vessels forming the tuft are likewise enormously enlarged, and very often the minutest branches are fully as large as the main artery of the corpus in a healthy state.

"Occasionally the tuft is broken up, and, instead of forming a compact mass, exhibits its individual branches separated from each other. At other times the branches of the tuft are actually larger than the primitive artery of the corpus. Under these circumstances it is singular that Mr. Bowman should have made the following remarks: — 'Though I have examined, with great care, many kidneys at this stage of the complaint, I have never seen, in any instance, a clearly dilated condition of the Malpighian tuft of vessels:' he adds, 'on the contrary, my friend Mr. Busk, an excellent observer, has specimens which undoubtedly prove these tufts not to be dilated in the present stage: and I possess injected specimens showing them in all stages, but never above their natural size.'

It is very possible that the peculiar injection used by Mr. Bowman may account for the fact which he mentions; and this conjecture is rendered extremely probable, as in the later stages of the disease, the Malpighian tuft becomes pressed upon by the adipose accumulation within, and, after undergoing compression, will permit the fluid used in the process of double injection to pass through rather than yield and distend. There are instances, again, in which the tufts are not enlarged, but appear healthy, even in organs otherwise extensively diseased: but it is important to add that these tufts, both in the second and third stages, when but slightly enlarged, or even not enlarged at all, will offer free passage to the injection, on the most gentle pressure, without even distending the whole of their vessels, and thus indicate their diseased condition.

" An enlargement of the renal arteries and dilatation of their branches, are also observable in this stage of the disorder.

" The capsule of the corpus, too, is in this stage very greatly increased in size, and during the process of injection becomes frequently filled with the injection thrown into the arterial system.

" The tubuli differ considerably from their healthy condition, being enlarged to two or three times their natural size, and aggregated together in masses, so as to lie in contact with each other, and form definite, roundish bodies: they are also extremely convoluted with numerous dilatations; frequently they are varicose. At other times they present distinct aneurismal sacs, which bulge out from one part of the wall of the tube, to which they are attached by a small neck or pedicle. Occasionally, some of the vessels of a convolution are smaller than the others, and their size nearly natural. The tubuli in the masses are so closely packed that the blood-vessels are evidently compressed, and rendered incapable of admitting an injection. At times, a tube, even at some distance from the corpus, becomes very convoluted and knotted into a mass.

" *Parenchyma.* — In cases where the kidney is much enlarged, the parenchymatous cells will be found not merely increased in size, but adipose deposition will be visible throughout them.

" *The Third Stage of the Disease.*—The kidneys are smaller than their natural size; hard, white granules are prominent on their surface, which is more or less lobulated; the capsule is adherent; vesicles of large size are frequently everywhere interspersed, and numbers of smaller ones stud the whole surface. On making a section, the organ is found to be deprived of blood; the cortical part contracted, the blood-vessels large and their walls thick.

" *Arteries.* — The arteries are in a more contracted condition than that described in the second stage; and the Malpighian tuft is often so changed from its natural state, that the greater part of its vessels are not capable of being injected.

" The capsule of the corpus has assumed a more contracted appearance.

"The arteries in this stage are so difficult to inject, that some anatomists have denied the possibility of the operation. The difficulty has its origin in the great pressure, which is exerted on the whole of the arterial system, by the contraction and hardening of the organ.

"*Veins.*—The veins in this stage present, on the surface of the organ, the well-known stellated aspect which arises from the gradual pressure exerted on the trunks, and the contraction of the organ.

Tubuli.—The tubuli are larger than in the preceding stage, and are gathered into rounded masses, which form the granules on the surface of the organ. The latter are of a white hue, and are most commonly fully distended with fatty depositions; though not unfrequently they appear like dark spots; the tubuli, in that case, being full of blood. A rounded appearance is generally characteristic of the granules, in each of which the component tubule forms innumerable convolutions. It is extremely difficult to inject the tubuli from the ureter; indeed, it is very rarely that it is possible to distend them from this source; nor is it an easy matter to fill them from the artery, though, as will be seen by the drawings, my efforts have not been without success.

The tubuli are filled with oily cells, granular matter, particles of various sizes, and blood globules.

"*Parenchyma.*—The parenchyma is hard, and is composed of elongated stellated cells, from the angles of which fine threads proceed, and communicate with each other."

The researches of Mr. Simon and Dr. Johnson, which appeared simultaneously in the Transactions of the Medico-Chirurgical Society for 1847, have brought to light other facts in the pathology of the kidneys. It is proposed in the next place to give an abstract of the observations of each of these observers, couched, as far as possible, in the language of the authors.

Mr. Simon's paper is entitled "On Subacute Inflammation of the Kidney."

"Without dwelling on those excessively rare cases, where idiopathic nephritis (independent of tubercles or of calculus) may, by its mere intensity, have ended in large suppuration or (almost uniquely) in gangrene, I may state that, in an infinite majority of instances, inflammation of the kidneys is subacute. It depends on some humoral derangement of the entire system, and commences as functional excitement manifest in an act of over-secretion. The morbid material which thus stimulates the kidney in its struggle for elimination will sometimes consist of products of faulty digestion,—the lithates or the oxalates; sometimes of matters cast upon the kidney in consequence of suppressed function in other organs — the skin, or the liver; sometimes will be the mysterious ferment of a fever poison — typhus, or scarlatina. In these several cases, whatever variety may exist in the detail of their causation, the essential symptoms during life, and the essential anatomical changes, are strictly identical in kind. They vary only in degree. The *materies morbi* seeks to affect its discharge by means of an increased activity in the secreting functions of the kidney: it stimulates it; and the result of the stimulation is not so much an increase of the watery secretion as it is an augmented cell growth in the tubules of the gland. This acceleration of function is incompatible with maturity of the secreted products; the epithelial cells undergo various arrests or modifications of development, and become more or less palpably imbued with evidences of inflammation.

"If attention happen to be directed to the state of the urine, that fluid will be found to present manifest signs of derangement. Microscopical examination will show in it numerous nucleated cells, which, in the hurry of over-secretion, have descended from the urinary tubules. Many free cytoblasts will likewise generally present themselves, together with a variety of those indefinite shapes, which are known to the Morphologist as abortions of cell-growth, and which constitute a series of connecting forms between the pus-globule and the healthy gland-cell. Mingled with these, in greater or less quantity, will be noticed also those remarkable fibrinous threads first described by Dr. Franz Simon in connection with renal disease. They are seen as exceedingly delicate, almost perfectly transparent and colourless cylinders, often containing in their mass some of the cell-forms just enumerated, or, not unusually, a few blood discs, resulting from hæmorrhage into the tubules.

"On several occasions, where the renal irritation has been gouty, I have seen crystals of lithic acid thus entangled in fibrin: in other cases, though far less frequently, I have distinguished crystals of oxalate of lime similarly enveloped. It is well known that these little cylinders are fibrinous moulds of the inflamed urinary tubules, some of the other contents of which they bring with them in their descent. They are thus quite as characteristic of the disease they attend as croupy expectoration is of tracheitis; and the cells or crystals included in them often afford the most valuable therapeutical indications.

"If patients chance to die while their urine is first furnishing the signs enumerated, it will often happen that the kidneys, in their general appearance, present no marked deviation from healthiness. Their cortical substance may, indeed, show the minute blood dots of intra-tubular hæmorrhage; or, more rarely, may present here and there a pin-head abscess. But often, perhaps most often, a superficial observer would pronounce the kidneys healthy; and, unless previous knowledge of the albuminuria had existed, they would receive no farther attention; or the Case-Book might contain that vaguest of all vague records — 'slight congestion of the kidney.'

"On minuter analysis, however, the microscope will reveal a large amount of disease. The ultimate tubules are found, as one might anticipate, gorged with an uneliminable excess of crude and vitiated secretion. Blood and amorphous matter, and an infinite range of cell-growth, from pus globules to the healthy germination of the gland, present themselves in various combinations; and among them shape or colour will sometimes enable us to discern the specific cause of the derangement—crystals of lithic acid or of oxalate of lime, or the ochreous tinting of bile. By products such as these the tubes are plugged, irregularly distended, and not unfrequently burst and annihilated. So close is the compaction of material, even in many of those tubes, that have no shaped inflammatory products within them, that they are plainly impervious; and it is only by artificial means,—by further tearing of the fragment, or by use of chemical agents, that we can satisfy ourselves that the dense plug in question consists but of agglomerated gland-cells.

"Now in the *post mortem* examination of these chronic cases, we may or may not find the kidneys materially contracted and deformed. It happens, to say the least, very frequently that the organ has preserved its full size and presents the ordinary colours. Perhaps it may have a cyst or two on its surface. Between such kidneys, and those which are all knobbed and puckered and wrinkled, there is not the essential difference which first sight would suggest. I shall first detail the changes which are latent in the healthier-looking kidney, and subsequently shall consider the anatomy of the contracted specimens, and analyse the circumstances which determine that apparent atrophy of the gland.

"In the first instance, then; In commencing the microscopical examination of the cortical substance, we partially find a similar state of tubes to that described in connection with the sub-acute attack—a state, namely, of unequal distention and of blocking up by their own accumulated products. In the cases which have lasted a long time, these products will often be found to have undergone material alterations, from the combined effects of pressure and absorption. The contents of the epithelial cells will have lost much of their natural fine granularity; so that the cells will appear, even when viewed singly, to have acquired a marked increase of solidity and substance. But, more than this—in many parts hardly a trace of tubularity will be found; the tubes have been burst; their contents have been interfused amid the matrix and blood vessels; and their débris may be found on opposite sides of a preparation,—here black and bloated, there pale and collapsed.

"Betwixt these trophies of disease there is a new manifestation. The interspace is crowded with a profuse development of cysts, apparently foreign to the healthy structure of the part. They are of all sizes; some are visible to the naked eye; some are of the magnitude of normal gland-cells, $\frac{\text{inch}}{1500-1000}$; but the majority are of an intermediate bulk,

$\frac{\text{inch}}{300-800}$. Even where smallest, they are distinguished by their sharp outline; and the larger ones are conspicuous by their roundness and transparency, for all above $\frac{\text{inch}}{1000}$ have predominantly fluid contents.

"To explain this very remarkable phenomenon, I take leave to digress for a moment from the straightforward pursuit of the inflammatory changes. Any one who has made a dozen *post-mortem* examinations must have observed cysts in the kidney; and there can be few pathologists who have not speculated on the origin of these growths. Their connection with chronic obstructive diseases of the kidney being notorious, some observers have supposed them to originate in dilatation of the Malpighian capsules; while others have referred them to distention of the urinary tubules. They exhibit great variety in size; they are seen every day as small as mustard seeds; they have been seen as large as cocoa nuts. Thus, they obviously range from a very conspicuous largeness to a size at which the naked eye loses them. On microscopical examination of cysted kidneys, the same uninterrupted gradation of size is seen to repeat itself. The larger vesicles fill the field of the microscope; the smaller ones diminish progressively, so that scores of them may be in the field at the same time.

"A section of cysted kidney, carefully examined with a sufficient magnifying power, may show an astonishing number of these minute vesicles; a number quite disproportionate to that of the larger cysts visible to the naked eye; so that, sometimes, by a single one of the latter class seen on the surface of the kidney, I have found myself guided to a disease which is substantially a vesicular transformation of the ultimate structure of the gland. The smallest cysts are simple nucleated cells, of the same size (or rather within the same limits of size) as the common secretory, or epithelial cells of the gland. From these cells they seem to be distinguished by their very definite outlines, and by their transparent fluid contents: but a step further in microscopical analysis shows that the distinction ceases at this point. They show no signs of a specific origin; no germs can be found for them other than might equally belong to epithelial development; it seems as though from the same germs — according, no doubt, to varying influences — healthy gland-cells might grow, or these fluid-holding cysts.

"Fuller investigation of the specimen reveals the following very suggestive fact: — the copious formation of cells occupies the place of tubes, holding their relation to the vascular plexus of the gland; and, as one gets to the periphery of the portion of gland thus transfigured, one finds the broken extremities of the original tubules, — some empty and collapsed, others obstructed and often dilated with morbid accumulation. In some cases this obstructive material contains a large proportion of fat, or consists of it almost entirely.

"In short, in pursuing the minute anatomy of the cysted kidney, we are conducted back to that same structural change which we found in connection with sub-acute nephritis, and demonstrably dependent on inflammatory processes; or sometimes we are led to a change in some respects similar to this, associated with what is known as the mottled condition of the kidney.

"The pathology of cysted kidney may accordingly be traced in either of two directions; from its first causation, or from its extreme phenomena. Following the latter course, we have ascended to a period in the history of cysts, in which they lie with numberless gland-germs amid the remnants of broken tubules. The unbroken tubules around show no growth of such cysts in their interior; many are distended, it is true, but not with cysts; their distention is of a kind that we have already investigated, — inflammatory, or perhaps fatty. From the smallness attained by the cysts, it seems quite obvious to me, that they cannot commence in any transformation of the tubes themselves, or of the Malpighian capsules. Accordingly, I find the same theory suggested by this method of inquiry, as when the morbid change had been traced descensively from its causes; viz. that certain diseases of the kidney (whereof sub-acute inflammation is by far the most frequent) tend to produce a blocking up of the tubes; that this obstruction, directly or indirectly, produces rupture of the limitary membrane; and that then, what should have been the intra-tubular cell-growth continues with certain modifications as a parenchytic development.

"During the growth of the cysts, they frequently exhibit an endogenous formation of cells which line them as an epithelium.

"If I am right in my statement of facts, and if my theory of the cyst-growth is sound, then the early stages of the process are certainly points of great interest. For no one accustomed to the interpretation of nature, can doubt the reparative tendency of these acts. The effused gland-germs are the last phenomena of the original disease, and the first of the attempted compensation. The transparent nucleated cysts, with their clear sharp outlines, are not mere dropsical epithelia; but are organised for secretion into their own cavities, so as at least to withdraw from the blood, if they cannot eliminate from the body, the materials which fill them.

"Returning now to the traces of inflammation in an uncontracted kidney, we have yet to ascertain the condition of its blood vessels. Numbers of the Malpighian bodies are extinct for all purposes of secretion; their vessels obliterated, their capsules wrinkled round them; they are dwindled, opaque, and bloodless. Sometimes the contraction of the Malpighian bodies is secondary on that rupture of their capillaries which Mr. Bowman has indicated as the source of intra-tubular hæmorrhage; which rupture, of course, may have arisen either in an augmented impulse of the arterial stream which fills them, or in an impeded circulation through the venous plexus into which they discharge themselves. But rupture of the capillaries is not the only cause of atrophy, to which these bodies are liable in the disease under consideration. The vascular tufts may be exposed to injurious pressure from materials accumulated in their capsules. Thus I have seen them flattened into a fourth of their natural compass, while the remaining larger portion of the capsule (probably continuous with an obstructed tubule) has been distended with a colourless and transparent fluid.

" Such is the minute anatomy of a kidney, which, having suffused from sub-acute inflammation, has undergone, in consequence, no noticeable alteration of volume, although having in its interior a very considerable new development.

" If the pathology of the uncontracted kidney be rightly understood, that of the contracted specimen will follow it naturally. It seems to me that, in the mere destruction and absorption of tissues, there is abundant explanation of the shrunken dimensions of a kidney which has passed through inflammatory changes. The tubes have burst, and a great portion of their contents has been removed by absorption; the Malpighian bodies have dwindled to a few; what, then, remains to make bulk? In the uncontracted specimen a false appearance of size is maintained by the adventitious cyst-growth, which I have described as filling the interstices of the organ. But the cysts are so much over and above the real kidney-structure; and if that succulent surplus could be removed, the result, as I have suggested, would be the falling together of wasted textures into a comparatively small compass. The cause of shrinking in the gland is the gradual absorption of spoiled material. This cause operates equally in all chronic cases, and its effects are to be traced in the uncontracted, as in the contracted specimen. The main difference between these two lies in the *more or less* of interstitial cyst-development; the most dwindled are those in which least of the new growth has arisen or has survived.

"I see no reason for believing that the interstitial effusion of lymph effects much towards the final contraction of the kidney. There are not wanting, I know, some pathologists who will assert it to be the great agent in the change; and who conceive they have seen the whole process of fibre-formation, according to the most approved foreign cell-theories. But I suspect that the observers of new fibre will often have confounded cause and effect. Coincidently with atrophy of the kidney, there occurs a contraction of the reticular matrix; but *that* contraction is, probably, consequent on a prior absorption of the intervening tissue. The meshes of the matrix come nearer together, and, in a given space, there is an excess of fibrous tissue, only because the material is withdrawn, which originally expanded that matrix through three times the space it now occupies.

"Up to the present point, I have studiously avoided introducing the ambiguous and controversial name of 'Bright's disease.' And now it will probably be asked, what relation to Bright's disease is borne by the malady I have treated of. Is it the same thing under another name? This question can be answered in a word, only when it shall have been settled what Bright's disease really is. The history of the complaint or complaints, included under that title, was, perhaps, originally systematised with too much haste. Starting from dropsy with albuminuria, and noticing that two chief forms of morbid appearance corresponded to that symptom (one, namely, where the kidney was large and mottled; the other, where it was contracted and knobbed, or irregularly granular), pathologists have considered these two forms as representing the extreme stages of one and the same disease.

"I must venture to express a doubt as to the justice of this generalisation. After investigating both classes extensively, I am convinced that the *mottled* and the *contracted* kidney do, *in almost every instance*, belong to different morbid actions, not to different stages of the same.

"The mottled kidneys, in an infinitely *large* proportion of cases, remain *large* and mottled to the end.

"I have now little further to add: with respect to the symptoms of sub-acute inflammation of the kidney, I will make one observation in addition to those already embodied in my paper. The descent of epithelium and its germs with the urine; the presence of albumen there, and sometimes of blood; the little casts of the tubules, — sometimes wrought of fibrin, sometimes of compressed epithelium; — these signs belong equally to the sub-acute inflammation and to the scrofulous disease. They are signals simply of renal irritation, whether from one cause or the other, and I suspect they only attend the scrofulous disease at that stage of its progress in which sub-acute inflammatory action is superadded to the primary fatty degeneration. Dr. Johnson's accurate observation has enabled us, under most circumstances, to diagnose the two classes from each other; for, in the scrofulous disease there will be always seen, as he describes, more or less oil entangled in the fibrinous casts, or gorging the cells which descend in the urine; a phenomenon which does not belong to the pure sub-acute inflammation."

The following pages embrace the more important portions of Dr. Johnson's communication, which is entitled, "On the Inflammatory Diseases of the Kidney."

"In a paper published in the last volume of the 'Society's Transactions,' I gave some account of fatty degeneration of the kidney, and declared my intention to make the inflammatory diseases the subject of a separate communication. On the present occasion, I purpose to bring before the Society the result of some observations on this very interesting and important subject.

"In the paper before alluded to, when referring to the condition of the kidney, which occurs as a consequence of scarlatina, I stated that "it is, in fact, an inflammation of the kidney, excited, like the inflammation of the skin which constitutes the eruption of scarlatina, by the passage through the part of the peculiar fever poison; and as the inflammation of the skin terminates in an excessive development of epidermis, and a desquamation of the surface, so the inflammation of the kidney excites an increased development of the epithelium which lines the urinary tubules: this material partly accumulates in and chokes up the tubes, while part of it becomes washed out with the urine, and may be detected in large quantities in that fluid by the aid of the microscope.

"To the account then given, which I believe to be essentially correct, subsequent observations enable me to make some important additions.

"On a microscopical examination, the convoluted tubes are seen filled in different degrees with nucleated cells, differing in no essential character from those which line the tubes of the healthy gland. The chief difference between these cells, which are the product of inflammation, and those which exist in health, consists in the former being generally of smaller size and more opaque and dense in their texture. It is very interesting and important to observe that, while the convoluted tubes are rendered opaque by this accumulation of cells in their interior, the Malpighian bodies are transparent and apparently quite healthy. The straight tubes which form the pyramids also contain an increased number of cells; but there is reason to believe, that these cells are not formed in these portions of the tubes, but that they are lodged there in their passage from the convoluted through the straight tubes; the latter being merely ducts leading into the pelvis of the kidney. Some of the tubes contain blood, which has, doubtless, escaped from the gorged Malpighian vessels lying within the dilated extremities of the tubes. There is no deposit outside the tubes. The essential changes in the kidney are an increased fulness of the blood-vessels, and an abundant development of epithelial cells, differing slightly in general appearance, size, and consistence, from the normal renal cells; this increased cell-development occurring in those portions of the urinary tubules, the office of which, as Mr. Bowman has suggested, is to excrete the peculiar saline constituents of the urine, while the Malpighian bodies, whose office is the separation of the water, are unaffected.

"The condition of the urine in these cases, is clearly indicative of the changes occurring in the kidney. After the urine has been allowed to stand for a short time, a sediment forms, and, on placing a portion of this under the microscope, there may be seen blood corpuscles, with epithelial cells in great numbers, partly free and partly entangled in cylindrical fibrinous casts of the urinary tubes; and, very commonly, numerous crystals of lithic acid are present. As the disease subsides, which, under proper treatment, it usually does in a few days, the blood, fibrinous casts, and epithelial cells, diminish in quantity, and finally disappear; but traces of the casts and cells are still visible some days after the urine has ceased to coagulate on the application of heat or nitric acid.

"The casts and cells which appear in the urine, when the disease is subsiding, are such as have remained some time in the urinary tubes before they have become washed out by the current of fluid poured into the tubes from the Malpighian bodies: many of the cells entangled in these casts have, consequently, become disintegrated and broken up into amorphous granular masses; thus presenting appearances which I shall presently show are characteristic of the casts occurring in cases of chronic nephritis. Such is the morbid anatomy of the kidney, and such are the characters of the urine occurring as a consequence of scarlatina.

"To the form of renal disease here described as occurring in connection with scarlatina, I propose to give the name of '*acute desquamative nephritis*.'

"The next form of inflammatory disease, to which I would direct attention, is one of great interest and importance. Two drawings by Mr. Westmacott represent the disease in two different stages: one represents a kidney in the earlier stage; the other shows a more advanced stage of the same disease. The kidney is never much enlarged; in the earlier stage, the size of the organ is natural, and the structure of the cortical portion appears confused, as if from the admixture of some abnormal product: there is also some increase of vascularity. As the disease advances, the cortical portion gradually wastes; the entire organ becomes contracted, firm, and granular; the pyramidal bodies remaining comparatively unaffected even in the most advanced stages: simultaneously with the diminution in size of the kidney, there is a decrease of vascularity. These changes occur very gradually: the disease is essentially chronic, having a duration in most cases of many months, and in some even of several years. It is almost confined to persons who are in the habit of partaking freely of fermented liquors; it is very commonly seen in those who have suffered from gout, and is not uncommon in those who, having indulged freely in the use of fermented liquors, have yet never had an attack of gout. It is sometimes, but I believe rarely, met with in those whose mode of life has been strictly temperate and abstemious. The symptoms usually attending the disease, are the following: — dropsy, which commonly is not excessive, often coming on only in the most advanced stages, and sometimes being entirely absent throughout the entire progress of the disease. The urine is commonly albuminous: it seldom, however, contains a very large quantity of albumen, and sometimes there is no coagulation on the addition of heat or nitric acid. The urine is sometimes high-coloured and scanty; but in most cases, it is rather abundant, pale, and of low specific gravity — from 1005 to 1010. In some instances, the quantity of urine is much greater than in health, and this increased quantity of urine is secreted by kidneys which are found after death to be contracted to one-third of their original bulk. In urine of such low specific gravity, there is, of course, a deficiency of the solid constituents, while the blood, which is much changed and impoverished, contains an excess of these materials.

"On a microscopical examination of the kidney, the nature of the above-mentioned changes is very clearly revealed, and, at the same time, the attending symptoms are satisfactorily explained. My account of these phenomena will be rendered more intelligible, if I give the facts and their explanation at the same time.

"On placing thin sections of the kidney under the microscope, some of the tubes are seen to be in precisely the same condition as in a case of acute desquamative nephritis; they are filled and rendered opaque by an accumulation within them of nucleated cells, differing in no essential respect from the normal epithelium of the kidney: this increase in the number, and this slight alteration in the character, of the epithelial cells, are the result of the elimination by the kidney, of mal-assimilated products, which are being continually developed in these gouty and intemperate subjects, and which are not normal constituents of the renal secretion.

"There must evidently be a certain limit to the number of cells which can be formed in any one of the urinary tubes; for, although some of the cells escape with the liquid part of the secretion, and so may be seen in the urine, as in a case of acute desquamative nephritis, yet, in many of the tubes, the cells become so closely packed, that the further formation of cells is impossible, and the process of cell-development, and, consequently, of secretion within that tube, are arrested. The cells, thus formed and filling up the tube, gradually decay and become more or less disintegrated. While these changes are going on in the convoluted portions of the tubes, the Malpighian bodies remain quite healthy, the Malpighian capsules for the most part transparent, and the vessels in their interior are perfect. From these vessels, water, with some albumen and coagulable matter, is continually being poured into the tubes; and, as a consequence of this, the disintegrated epithelial cells are washed out by the current of liquid flowing through the tubes, so that, on examining the sedimentary portion of the urine, we find in it cylindrical moulds of the urinary tubes, composed of epithelium in different degrees of disintegration, and rendered coherent by the fibrinous matter which coagulates amongst its particles. The appearance of these casts are quite characteristic of this form of 'chronic desquamative nephritis.'

"There is reason to believe, that when the process of cell-development and of secretion have once been arrested, by the tube becoming filled with its accumulated contents, it never recovers its lining of normal epithelial cells; but, when the disintegrated epithelium has become washed away from the interior of the tube, the basement membrane may be seen, in some cases, entirely denuded of epithelium; in other cases, a few granular particles of the old decayed epithelium remain: and again, in other instances, the interior of a tube, which has been deprived of its proper glandular epithelium, is seen lined by small delicate transparent cells, very similar to those which may sometimes be seen covering the vessels of the Malpighian tuft.

"It now becomes interesting to ascertain what further change the tube undergoes, after having lost its normal epithelium. It is quite certain that, as a general rule, the Malpighian bodies remain unaffected, both in structure and in their office of secreting the watery constituents of the urine, until the whole of the disintegrated epithelium has been washed out of the tubes. Of this there are two proofs; the first is the fact of a very long convoluted tube having its contents completely washed out, and its basement membrane left quite naked: this could happen only as a consequence of a current of liquid passing through the tube, and there is no known source of such a current but the Malpighian vessels: the second proof is still more convincing and satisfactory, and it is this, — that a tube may often be seen entirely denuded of its epithelial lining, and continuous with a Malpighian body, in the interior of which the vessels are quite perfect.

"Now, a tube of this kind deprived of its lining of normal epithelium has manifestly lost its power of separating from the blood the solid constituents of the urine, while, the Malpighian vessels remaining unaffected, the power of secreting water remains. Further, it appears probable not only that the Malpighian body continues to secrete water, but that the whole length of a convoluted tube thus deprived of its proper epithelium, and either remaining naked or lined by delicate nucleated cells, such as those which cover the Malpighian vessels — that the entire length of such a tube becomes a secretor of water, which it abstracts from the portal plexus of vessels on its exterior. This is rendered probable by the appearance of the tube itself; and the probability is still further increased by the fact of the tubes becoming, in some cases, dilated into cysts, which usually contain a simple serous fluid, without any of the solid constituents of the urine.

"It has long been supposed that the simple cysts, which are so commonly seen in connection with some forms of renal disease, are, in fact, dilatations of the urinary tubes. I am not aware that any satisfactory evidence has been adduced in confirmation of this opinion, but there are some facts and arguments which appear to me abundantly sufficient to prove the accuracy of the notion.

"1st. The tubes thus denuded of their epithelium are often seen much dilated. I have repeatedly seen them three or four times exceeding their normal diameter. In some cases the dilatation is very sudden, so that the tube assumes a globular form, and appears to bulge in the intervals of the fibro-cellular tissue, in which the tubes are packed: in some cases, too, the basement membrane appears thickened in proportion to the dilatation of its cavity. Now, this process of dilatation having once commenced, and the lower end of the tube becoming closed by a deposit in its interior, or by pressure from without, there is no reason to suppose that the process may not continue until a cyst as large as a pea or a walnut is formed.

"2ndly. But there are other facts which afford a very interesting and remarkable confirmation of this notion. In a case of simple acute or chronic nephritis, the quantity of oil in *the secreting cells* of the kidney is very small; sometimes, indeed, none can be detected. But it frequently happens that, after a tube has been stripped of its secreting cells in the manner before mentioned, an accumulation of fatty matter occurs in its interior, the denuded basement membrane becomes scattered over with separate oil-globules, and these increase in size until they form masses of fatty matter, having much the appearance of adipose tissue; and such a mass is frequently washed out from the tube, and may be detected in the urine. This occasional filling of the tube with fatty matter is very interesting in connection with the fact, that in some cases the cysts, which are supposed to be dilated tubes, are also found filled with the same material. In two cases, I have found a cyst as large as a hazel-nut, quite full of oil, presenting all the characters of that seen in the tubes which have lost their epithelium in consequence of chronic inflammation.

"The evidence, then, of the simple serous cysts being dilated tubes, is the following: — 1st. That tubes are often seen much dilated and thickened. 2d. As the inner surface of the tubes has the appearance of being endowed with the power of secreting water, so the cysts usually contain a simple serous fluid. 3d. As an accumulation of oil occasionally occurs in the tubes, so the cysts are in some instances filled with the same material. 4th. *There is no reason to suppose that these cysts have any other origin.* It appears probable that the Malpighian bodies could not become dilated into cysts, because an accumulation of liquid within the Malpighian capsule would necessarily compress and obliterate the vessels of the Malpighian tuft, and so would cut off the further supply of fluid.

"Another change consequent upon the destruction of the cells which line the urinary tubes is, a diminished supply of blood, and a gradual wasting of the tube. I have already shown that there must be a close connection between an increased development of epithelial cells, and an increased afflux of blood to the part. This is well seen in a case of acute desquamative nephritis, and, *vice versâ*, a more or less complete destruction of the epithelial cells will be attended by a corresponding diminished afflux of blood, and a consequent atrophy of the part affected. In every kidney which has been the subject of chronic inflammation, there may be seen tubes contracted in different degrees, as a consequence of the destruction of their epithelial lining: in some instances, the basement membrane becomes folded, and presents an appearance not very unlike white fibrous tissue. As a consequence of this wasting of successive sets of tubes, there is a gradual diminution in the bulk of the cortical portion of kidney, until, at length, the entire organ becomes small, contracted, and granular. When a thin section of a kidney, thus atrophied, is placed under the microscope, there may be seen an abundance of fibrous tissue; and this has often been described as new fibrous tissue developed during the progress of the disease; whereas it is, in reality, nothing more than the atrophied remains of the basement membrane of the tubes, with the healthy fibrous tissue arranged in the form of a net-work in which the tubes are packed, and which now appears more abundant in consequence of the wasting of the tubes.

"It has already been stated that the Malpighian bodies are unaffected in the progress of this disease; and this is true, in so far as they remain, for the most part, free from any deposit or accumulation in their interior: but they must necessarily be affected by the changes occurring in other parts of the organ. Thus the destruction of many of the Malpighian bodies is a necessary consequence of the simultaneous wasting of the vessels and tubes which occurs in the advanced stages of chronic nephritis: and, during the progress of the disease, the vessels of the Malpighian tuft will be in a state of more or less active congestion, in proportion to the rapidity of secretion and of cell development in the tubes; and one consequence of this congestion of the Malpighian bodies will be the escape of serum into the tubes, and the mixture of albuminous matter with the urine. The quantity of albumen in the urine will be great in proportion as the disease approaches in activity to that form which I have called 'acute desquamative nephritis.' When the disease is chronic and inactive, there may be no albumen in the urine, or, it may be present in quantities so small as not to be detected by the ordinary chemical tests. In such cases, as, indeed, for the accurate discrimination of all forms of renal disease, the microscope will be found an invaluable aid. It must be remembered that the essential change in this disease is a destruction of the epithelial cells in the manner already described; the best evidence of this change being in progress is, the presence in the urine of moulds of the urinary tubes, composed of more or less disintegrated epithelium; and such evidence I have repeatedly obtained, when no albumen could be detected by the ordinary heat and nitric acid tests.

"A sufficient explanation has already been given of the small quantity of the saline constituents excreted by the kidneys in cases of chronic nephritis. It is manifest, that, if the epithelial cells are the agents by which the solid constituents of the urine are separated from the blood, a deficient excretion of these materials will be a necessary consequence of the greater or less destruction of the epithelial cells.

"Before concluding this communication on the inflammatory diseases of the kidney, it appears desirable to allude very briefly to the subject of my last paper, — viz. 'Fatty Degeneration of the Kidney;' my object being to show how essentially distinct are the two forms of disease; and, at the same time, to explain the manner in which they are sometimes combined.

"For some months past, I have been aware that fatty degeneration of the kidney occurs in two distinct forms.

"In the simple fatty degeneration of the kidney, all the tubes become almost uniformly distended with oil. In a slight degree and in the earlier stages, it is often found, after death, in cases where there is no reason to suspect that it has been productive of any mischief during life:

it is not until the fatty accumulation has attained a certain amount, that the functions of the kidney are interfered with. It is this form of fatty degeneration of the kidney which occurs in animals, as a consequence of confinement in a dark room. In the human subject, although in the earlier stages it is a very common occurrence, yet in the more advanced stages it occurs less frequently than the *second form of fatty degeneration.* This form of the disease is represented in the 5th figure of Dr. Bright's 3d plate, as well as in the 1st, 2d, 5th, and 6th figures of Rayer's 8th plate. The cortical portion of the kidney, to use the words of Dr. Bright, is soft and pale, and interspersed with numerous small yellow opaque specks. The kidney is generally enlarged; sometimes it is even double the natural size. In some cases, the cortical portion is somewhat atrophied and granular; but neither in this, nor in the first form of fatty degeneration of the kidney, does that extreme wasting with granulation occur, which is so frequent a consequence of chronic nephritis.

"On a microscopical examination, the convoluted tubes are found filled in different degrees with oil; some tubes being quite free, while others are ruptured by the great accumulation in their interior. The opaque yellow spots scattered throughout the kidney, are neither more nor less than convoluted tubes distended, and many of them ruptured by their accumulated fatty contents; just as the red spots are found to be convoluted tubes filled with blood. The cells which contain the oil are for the most smaller, more transparent, and less irregular in their outline than the ordinary healthy epithelium; they are increased in number, and many of them are so distended with oil as to appear quite black. In parts of the same kidney, there may commonly be seen some of the appearances already described as indicative of desquamative nephritis. This form of disease is very commonly combined with fatty degeneration of the liver; but less frequently than is the first form of fatty degeneration of the kidney.

"The peculiarities of the second form of fatty degeneration of the kidney result from a nephritic condition of the organ, dependant on the presence of some irritating material in the blood being associated with a tendency to fatty degeneration; this tendency resulting from the presence in the blood of mal-assimilated fatty matter. The nephritic condition is manifest by an increase in the number of epithelial cells; the tendency to fatty degeneration, by a filling of many of these with oil. Although the two conditions are combined in this and in similar cases, it must be remembered that they are essentially distinct in their nature and origin. Each cell which escapes from the kidney carries with it a portion of the morbid material. The oil is in the form of visible globules; while the cells which contain no oil doubtless contain some other material which is invisible, or less readily seen than the oil globules.

"I have now distinguished and described four conditions of the kidney:—

"1st. Acute desquamative nephritis:
"2d. Chronic desquamative nephritis:
"3d. Simple fatty degeneration: and
"4th. A combination of fatty degeneration with desquamative nephritis.

"The diagnosis of each of these conditions of the kidney, during the life of the patient, is a matter of the greatest importance with reference to prognosis and treatment; and the diagnosis may be made with ease and certainty by a microscopical examination of the urine."

The most recent researches in this country into the pathological anatomy of the kidneys are those of Dr. Gairdner *, who has evidently devoted to the elucidation of this subject not a little time and attention; and the results of these investigations will now be given in as concise a form as possible.

Dr. Gairdner treats of his subject under the three following heads:—1. Exudation: 2. Lesions affecting chiefly the vascular system: and 3. Lesions of the tubes and epithelium—an arrangement which will here be followed.

Exudation.

Exudations into the substance of the kidney give rise to a great variety of external appearances, which have been well figured and described in the works of Bright and Rayer.

Exudations from the blood-vessels may have their seat in any, or all the tissues of the kidney; their usual situation, however, is in the interior of the tubes, but it also occurs frequently within and around the Malpighian bodies, and in the intertubular tissue, the tubes being quite clear; it is also seen infiltrated through all the tissues in the form of a homogeneous mass, which contained within it the whole of the anatomical elements of the kidney.

The appearance of the kidney, as altered by the presence of exudation in the tubes, is subject to variations depending on the amount of the deposition, and its partial or general character: one almost invariable effect of the repletion of the tubes, is a corresponding diminution in the fulness of the vessels of the cortical substance, particularly of the Malpighian vessels, and the capillaries surrounding the tubes. This effect is evidently the result of pressure.

It is thus evident that Dr. Gairdner does not ascribe the albuminous urine of Bright's disease to secondary congestion, or rupture of the Malpighian bodies, caused by the distention of the tubes from accumulated fat; and in this particular his views differ from those already cited of Dr. George Johnson.

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* Contributions to the Pathology of the Kidney, by William T. Gairdner, M.D. Monthly Journal of Medical Science, 1848.

The volume and weight of kidneys containing exudation in the tubes are frequently much increased.

The exudation may be diffused throughout the organ, or it may be confined to certain portions of it. "It then tends," writes Dr. Gairdner, "to accumulate in certain sets of the convolutions in which the urinary current is least active. These becoming partially blocked up, and ceasing entirely to secrete, are thrown aside from the outward current of secretion, and become a centre of attraction for further deposit, just as the eddies and still waters at the sides of a rapid stream receive from it the foam and floating bodies brought down from above. In this way, more and more of the adjacent loops of tubuli are filled with the abnormal deposit, and become added to the former nucleus, until the masses of exudation, thus imprisoned within tubules through which no secretion passes, form irregularly rounded bodies in the cortical substance, visible to the naked eye, more or less prominent on the surface of the organ, and usually of an opaque yellowish colour. These are the granulations first described by Dr. Bright."

Intratubular exudations, excluding tubercular and cancerous deposits, may be considered under three heads: *a*, crystalline or saline matters deposited from the urine; *b*, oleo-albuminous, or granular exudations from the blood plasma; *c*, exudations forming pus.

a. The most common saline deposit met with in the tubes of the kidney is the amorphous urate of ammonia; inasmuch as this salt is a constituent of healthy urine, its presence in moderate quantities is merely a normal post-mortem appearance, the deposition of the salt resulting from the cooling of the urine after death. In some instances, however, it is present in such large quantities; and in these it occasions such an alteration in the appearance of the kidney, that it might, unless discriminated by means of the microscope, be attributed to disease.

Under the microscope, the urate of ammonia presents the appearance, when within the tubes, of a fine molecular shading, which entirely obscures the nuclei; the distinguishing character of this deposit is its ready solubility in the dilute acids, as the acetic or nitric.

In one case Dr. Gairdner detected the presence of crystals in the tubes, which, from their appearance and colour, he entertained little doubt were of uric acid, although, from their minute quantity, they could not be submitted to chemical examination.

In this case the urine was of low specific gravity, and albuminous, although there was no apparent exudation within the substance of the gland.

b. Dr. Gairdner includes under the term "oleo-albuminous exudations from the blood plasma," those exudations which are fatty in their nature, as well as the inflammation globules, granular corpuscles, or exudation granules, and corpuscles of different writers.

The facts connected with the presence of fatty exudations in the kidney, have been almost exhausted by the excellent researches of Dr. Johnson; one additional fact of interest has been added by Dr. Gairdner. This observer finds that the fatty granules or globules are not confined to the epithelial cells, but also that they may be freely disseminated throughout the tubes: the tubes containing the fatty granules sometimes appear distended, at other times smaller than natural, as if they had contracted around the fat.

It is probable that the presence of the fatty globules in the tubes results from the rupture and disorganisation of the cells which first contained them, and that, therefore, their location in the tubes themselves indicates a more advanced condition of this form of renal disorganisation.

c. The occurrence in the cortical substance of deposits of pus is not very uncommon: their most usual form is that of small abscesses, rarely exceeding the size of a pea, and frequently much smaller; sometimes confluent, and irregularly disseminated throughout the cortical substance.

The granular (oleo-albuminous) form of exudation is frequently found occupying the tubes of the kidney, and occasionally also within the capsules of the Malpighian bodies: when in large quantity in the latter situation, the tuft of vessels becomes compressed, shrunk, and, in most cases, invisible.

Under the heading "Partial distribution of the oleo-albuminous exudation," Dr. Gairdner describes, in the following terms, a peculiar pathological condition of the kidney:—"I have already described the formation of granulations as dependant on the accumulation of deposit in particular groups of tubules in the cortical substance. In such cases, however, the affection is probably, at first, general; they are very different from the form now to be described, in which the deposit is quite limited in extent, and isolated.

"There are occasionally met with, on removing the capsule from the surface of a kidney, irregular patches, of a paler colour than the rest of the organ, sometimes a little elevated, sometimes depressed below the general surface. Their boundary is quite abrupt, and they are frequently surrounded by a well-marked rose-coloured areola, extending more or less into the surrounding substance. On making a section of these patches, they are found to penetrate into the cortical substance, and sometimes even a certain way into the pyramids. The vascular areola, when present, extends round them in every direction, and is found, on examination, to consist of highly-injected Malpighian bodies and capillaries, with or without extravasation; the colour of the patches varies from yellowish-grey to gamboge-yellow: their consistence is generally firm. On microscopic examination, they present a large amount of exudation, varying from the molecular to the large granular form. In some cases the tubes may be seen filled with exudation; in others they appear to be in great part obliterated. In one case I found the Malpighian bodies quite free of exudation; they preserved their usual arrangement, and were readily discoverable by a simple lens on the surface of the section. The parts of the kidney not involved in the deposit, generally present no abnormal appearance."

Lesions affecting chiefly the vascular system.

Variations in the vascular condition of the kidney may, and frequently do exist, totally unconnected with organic change: thus this organ, like all other vascular structures, may be either in a hyperemic or anæmic state; and these conditions may effect either the entire vascular system, or they may be local only, or they may involve respectively the venous or arterial vessels. The veins of the kidney are disposed chiefly in two situations, viz., on its surface, and in the substance of the pyramids, the cortical substance containing but few veins. On the surface the larger vessels follow a somewhat stelliform arrangement, while the capillaries themselves form a meshwork, the meshes describing small pentagonal or hexagonal spaces, in each of which a single convolution of a tube is situated. The state of these vessels is subject to much variation; they may be in an anæmic condition, and scarcely visible, or they may be gorged with blood; in some instances this engorgement is general, and in others it is confined to the stelliform vessels just referred to. These conditions, as already observed, may be totally unconnected with disease; when, however, there is great irregularity of injection, amounting to marbling of the surface, and great increase in the size of the stellar vessels, these are generally pathological, and result either from partial obliteration of the venous network, or of the extrusion of the blood from it, through over-distention of the loops of tubuli which form the intervening pale spaces.

"The engorgement of the capillaries and Malpighian tufts gives rise to two conditions: first, a generally diffused heightened colour of the cortical substance; and second, increase and greater distinctness of the vascular striæ, running from the base of the pyramids to the external surface. This latter species of injection often exists to a great extent, without any corresponding injection of the rest of the kidney, and in some instances the red points composing the striæ are so much increased in size as to form considerable petechiæ (one line in diameter, or upwards), in which case the petechiæ usually extend to the surface, occupying the intervening spaces of the venous polygons above mentioned. This appearance was supposed by Rayer to occur from simple hypertrophy and vascular injection of the Malpighian bodies; but Bowman *, who has shown that the Malpighian bodies do not exist on the surface of the kidney, has also given a better explanation of such petechiæ, which he holds to arise from rupture of the Malpighian tuft, with extravasation of blood into the surrounding tubes. He argues that the petechiæ are of irregular form, and of much larger size than the Malpighian bodies have ever been observed to acquire. He gives, also, a figure representing the occurrence of a similar appearance, from artificial injection, at the surface of the kidney. In this figure the loops or knuckles of the tubuli are seen filled with injection, presenting themselves at the surface, and surrounded by the venous network."

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* Philosophical Transactions, 1842.

The correctness of this explanation cannot be doubted; and it is therefore evident that the occurrence of these petechiæ must be considered as invariably morbid.

The anæmic condition of the kidney, when the result of disease, is generally accompanied by increase in the size of the tubes from contained secretion; and it is the pressure of these on the surrounding vessels that occasions their empty condition, and, in some instances, even obliteration. The vessels of the Malpighian tufts likewise become involved, and the Malpighian corpuscles themselves, thereby altered in form, from being globular they become angular and compressed.

Under the heading "Congestion followed by permanent obliteration of the Capillaries," Dr. Gairdner has described a lesion of the kidney, which he has designated by the term "*waxy degeneration*," in contradistinction to the "*fatty degeneration*."

"The appearances most characteristic to the naked eye of this form of lesion, are those so admirably figured and described by Rayer as the second form of his 'néphrite albumineuse.' The kidneys are generally increased in size, sometimes very remarkably so. Their consistence varies: they are sometimes more flaccid than in the natural condition, but always preserve considerable tenacity. The surface is either quite smooth, or more or less depressed and furrowed. The venous vascularity assumes, to a considerable extent, the stellate form; the polygons are mostly absent; and the extreme irregularity and abruptness of distribution of the superficial veins gives to the surface a variegated or 'marbled' appearance, which is quite characteristic of this stage of the affection. (See Rayer, Plate VI. *figs*. 2, 3. 5; Bright, Plate II. *fig*. 1.) Occasionally, also, amid this unequal injection, there are to be found scattered petechiæ, indicating recent extravasations of blood into the tubes. On section, the cortical substance has considerable volume, and presents a smooth, glistening, almost semi-transparent appearance, which cannot be better distinguished than by the term *waxy*. It may partake in a slighter degree of the variegated character of the surface; more commonly it is of uniform appearance, and of a yellowish or fawn colour, sometimes verging into a pale flesh tint. The vascular striæ of the cortical substance are generally to be traced by a more or less distinct injection, and a few injected Malpighian bodies, or petechiæ of extravasation, are sometimes dispersed through the section. (See Rayer, Plate X. *fig*. 3.) In other cases, a little further advanced, both the striæ and the Malpighian bodies are nearly destitute of blood. (Rayer, Plate X. *fig*. 1; Bright, Plate II. *fig*. 1.) The pyramids frequently retain their normal vascularity; sometimes, however, they are of a pale colour and their bases are indistinctly marked,—a condition which indicates the progress towards a further disorganisation.

" When a kidney in this condition is carefully and minutely injected, the greater proportion of the cortical substance remains impervious; the injection, however, can frequently be made to penetrate as far as the cortical striæ, and even to some of the Malpighian bodies. (See Rayer, Plate X. *fig.* 2; Bright, Plate II. *fig.* 3.)

" From these circumstances it is obvious, that the lesion above described consists in an obliteration or obstruction of the capillary system of vessels throughout the organ, and a partial obliteration of the veins on its surface. There is also every probability that this condition is secondary to one in which there is a high degree of congestion of the organ. The extravasations, the occasionally injected Malpighian bodies, and the highly injected though partially distributed stellar veins, leave no doubt that the state of congestion described as the first form of albuminous nephritis by Rayer, is really the antecedent of the present or second from.

" To any one who is familiar with the *marbled* and *waxy* kidney here described, there can be no difficulty in recognising a further stage of the same lesion, in which the organ is perfectly pale both on the surface and on section, with the exception perhaps of a very few stellated superficial veins. The kidney in this stage (the transition to which seems to be represented in Rayer, Plate VI. *fig.* 4.) is still heavy and voluminous; it acquires additional firmness and elasticity, and assumes much of the general appearance of a true non-vascular texture. It varies from a light yellow to a fawn colour, which extends to the pyramids, the bases of which become still more confused and intermingled with the cortical substance than in the marbled kidney. The capsule is frequently more firmly adherent to the external surface than in health.

" From the pale and yellow appearance of the kidney in this stage, it is very apt to be mistaken, even by a practised eye, for an extreme degree of the fatty degeneration. A well-marked example, indeed, will hardly give rise to this error, if attention be directed to the degree of firmness of the organ, the peculiar lustrous character of the cut surface, and the entire absence of the opaque granulations of Bright, or of that dull tint which distinguishes the excessive degrees of the fatty disease. The appreciation of these characters is, however, more difficult where, as sometimes happens, exudation is also present; and the distinction which has escaped the acute observation of M. Rayer, has undoubtedly been overlooked by many other observers.

" The microscopic characters of this lesion are chiefly negative. There is not unfrequently an entire absence of exudation; indeed, in the most marked cases of the lesion I have seldom found even the slightest trace of any abnormal deposit. Occasionally, however, there is a very minute quantity of fatty exudation in the tubes, generally in very small granules, and scattered throughout the organ. The tubes are either natural, or in the advanced stages pass into some of the states hereafter to be described. The capillary vessels surrounding the tubes are not visible, and in their place there is fibrous tissue, which in this form of lesion always appears somewhat exaggerated. The Malpighian bodies are also frequently seen in process of obliteration, and surrounded by dense capsules of fibrous tissue. The epithelium is frequently altered in character, but its changes follow no fixed rule.

"The absence or scantiness of exudation, taken in connection with the extent of degeneration appreciable by the naked eye, are amply sufficient characters to distinguish this lesion from the extreme stages of the fatty disease."

Lesions of the Tubes and Epithelium.

Some of these lesions have been already described under the head of exudation; but there are others which are not less important than those formerly alluded to, and which are very frequently found in connection with them.

Imperfect Development of the Epithelium Cells and Nuclei. — The epithelium cells and nuclei vary in size and characters within certain limits even in healthy kidneys; the nuclei less so than the cells themselves; but in all kidneys, whether healthy or diseased, the nuclei which are most closely adherent to the basement membrane are less perfectly circular, and of considerably smaller size, than those lining the tubes and surrounded by complete cell-walls.

Those acquainted with the normal anatomy of the kidney will be able to determine the limits of variations in the epithelium and nuclei compatible with a state of health.

In very many pathological conditions of the organ, the nuclei occur in various places almost wholly devoid of cell-walls. They may be more abundant or more scanty than usual; and often appear in great profusion, huddled together in confused masses, and mixed with shreds of membrane and amorphous molecular matter, not soluble in acetic acid. This appearance of débris, which no doubt results from disintegration of the cell-walls, most frequently occurs in kidneys which are abnormally soft and large, and from the cut surface of which an unusually large quantity of turbid whitish juice may be scraped. Such softened and altered kidneys occur frequently in fever and other diseases.

A more unequivocal pathological change (often occurring along with the above) is the small size and altered form of the nuclei throughout the organs, these not being more than half the usual size and always destitute of cell-walls. Sometimes they float scattered and solitary in the field of the microscope; at other times they appear aggregated together either by twos or threes, or in much greater numbers, the connecting medium being a transparent and filmy substance, the nascent or undeveloped cell-membrane which has separated from the basement membrane, along with the half-developed or young nuclei above described. These aggregations of young nuclei are sometimes mingled with the amorphous débris of effete epithelium or with granules and molecules of oleo-albuminous exudation, or of lithate of ammonia, which communicate to them a dark and confused appearance: not unfrequently, also, these masses, when freed from the tubes, retain more or less of their form, and present so exactly the appearance of the casts of the tubuli seen by Franz Simon, and many other observers, in the urine, as to leave no doubt of their identity with these bodies.

Desquamation of the Epithelium. — The changes above described are generally accompanied by an extremely rapid generation of nuclei, which are separated from the basement membrane in an imperfect state, and carried away along with the urine, in which they may be readily detected.

In some cases of desquamation of the epithelium, it is scarcely possible to recognise any departure from the usual condition of the kidney, either with or without the assistance of the microscope. The degree of vascularity is very various in different specimens, and the epithelium thrown off is so quickly resupplied, that there is no very observable change in the microscopic condition of the tubules. In one very intense case, in which ten pounds of very watery urine loaded with an epithelial sediment were passed daily for some weeks before death, the kidneys were small, flaccid, and bloodless; many of the tubes were quite full of nuclei closely heaped together; some of the nuclei were under-sized; the cells, when entire, were much compressed and angular. In another instance where urine was passed in large quantity and full of epithelial débris, during the last two months of life, the kidneys were found in an opposite condition, viz. large and congested, and with a firmness and smoothness of section like the first stage of the waxy degeneration formerly described. In this case, the condition of the tubuli was in most parts quite natural; in some, however, there was extravasated blood, and in others the epithelium had accumulated in abnormal quantity. In both these cases there was imperfect development of the epithelium, but cases have occurred to me in which this character was by no means well marked: the crowding of the tubes with nuclei, although frequently found in the earlier stages of desquamation, is not invariably present; and the tubes were even seen to be gorged with epithelium in a case where none had been separated from the urine for weeks before death.

So long, therefore, as the epithelium is freely regenerated, the kidneys may present a tolerably healthy appearance, even on minute examination: after prolonged disease, however, further changes take place; the epithelium becomes more sparingly generated, and is thrown off in the coherent masses above described, leaving the basement membrane in portions bare, or with a few scattered oval nuclei, much smaller than those cast off, adhering to its inner surface. In the microscopic examination of organs in this condition, there are frequently seen films of such exceeding delicacy and transparency as to be only visible by very careful management of the light: they preserve the shape of the tubules, and contain no nuclei or structures of any kind. Similar films are occasionally seen in the sediment of urine. They are probably thrown off from the denuded basement membrane.

" *Obliteration of the Tubes.*—The basement membrane, which, with the few closely adherent oval nuclei above described, is now the sole remaining structure of the tubes, soon undergoes a change. It loses the cylindrical form proper to it in the fresh and natural kidney, and becomes flattened by the pressure of the surrounding parts. Its cavity is thus obliterated, and what was a tube assumes the appearance of a transparent riband, dotted here and there with small oval nuclei, which, when seen at the edges, appear to be inclosed between two layers of membrane. These riband-shaped portions of membrane appear to present considerable tenacity and elasticity; by their greater density, and by the constant presence of the small oval nuclei so often mentioned between their layers, they are in most cases readily distinguished from the delicate films which have been referred to above. They are very various in diameter, but are always inferior in this respect to the normal tubes; and they appear to break up spontaneously into smaller portions; each of which contains from one to six or more nuclei: these portions are of various sizes; they are usually broadest in the middle, and taper to a point at both ends. The smallest of them contain only a single nucleus, and present an appearance in every respect like that of young fibres of areolar texture, or those fusiform cells, which have been called fibro-plastic. I think it probable that the whole of the diseased basement membrane ultimately splits up into fibres of this kind. While these changes are proceeding, the capillary vessels, which have ceased to be subservient to secretion, are usually obliterated: the consequence of this double obliteration of vessels and tubes is a considerable degree of atrophy in the diseased parts; and as the atrophy takes place at first chiefly in the cortical substance, great irregularities of the surface generally supervene: thence arises the appearance so well described and figured by Dr. Bright (Plate III. *fig.* 2.), in which, from the atrophy of the cortical substance, the bases of the pyramids ' are drawn towards the surface of the kidney.'

" When oleo-albuminous exudation supervenes on the above derangement of the tubes, or when desquamation supervenes on the former (circumstances which I conceive to be of very common occurrence), the exudation most commonly takes the form of the granulations of Bright, which are deposited chiefly in the diseased tubes; and the atrophy proceeding around these, they become salient, and the surface generally irregular, giving rise to the tuberculated state of the surface so common in all the later stages of the granulated kidney. (Bright, Plate III. *fig.* 1; Rayer, Plate VII. *fig.* 6. Plate IX. *fig.* 8.) As the atrophy, however, proceeds, the granulations are gradually absorbed; and when the kidney has become extremely contracted and irregular, they often in part disappear.

"The atrophied portions of the kidney are usually exsanguine, and of a tawney or drab colour: they have considerable hardness and toughness. Examined microscopically, they appear to consist of fibres and fusiform cells in great abundance, and more or less granular exudation, according to circumstances. According to Henle, Eichholtz, Gluge, and others, these fibres are in great part new formations; Johnson and Simon consider them as nothing more than the compressed parenchyma of the gland, from which all the other normal elements have disappeared. I look upon them as formed in great part by the breaking up of the basement membrane of the tubes (as above described), as well as from the parenchyma and obliterated capillaries. It is not improbable, however, that, in addition to these elements, some new fibrous tissue is formed.

"The extreme stage of the atrophied kidney is nearly the same, whether exudation have existed or not.

"*Microscopic Cyst-formation.*—It occasionally happens, on examining the section of a kidney with the microscope, that we see scattered through some parts of the section a few small clear vesicles, of nearly circular or oval form: they are either of a very pale straw colour, or nearly colourless, and are perfectly clear and translucent, with a very distinct shadowed margin, which causes them to stand out in bold relief from the other textures composing the section. Their diameter is usually from $\frac{1}{40}$th to $\frac{1}{15}$th of a millimetre, but in this respect they vary considerably; sometimes they appear to lie in the tubular areolæ, and at other times to be unconnected with these. Very rarely they have appeared to contain a few granules; most commonly, even when there is granular exudation around them on every side, they contain nothing but clear fluid. Their refractive power is not so great as that of oil, while it is much greater than that of the spherical cells of the tubes: hence their distinct and characteristic shadowed outline.

"These bodies (which, however, have never appeared to me to present distinct nuclei) are probably the same with the "nucleated cells or vesicles" described by Mr. Simon as resulting from the extravasation of the epithelial cells into the intertubular tissue, and as progressively enlarging, so as to form the cysts visible to the naked eye, which are so common in diseased kidneys. To these structures he attaches great importance in the pathology of the kidney, conceiving them to be the invariable result of the desquamative disease when of long standing; the kidney being, in Mr. Simon's opinion, changed more or less into an aggregation of microscopic cysts, which either undergo absorption and lead to atrophy of the organ, or increase in size and monopolise its texture. Thus, according to Mr. Simon, the serous cysts so common in the kidney result from an enormous development and hypertrophy of extravasated epithelium cells, which assume the character of the vesicles he describes, and acquire the power of increase and endogenous development.

" Whether the bodies described by me above are the same with the vesicles of Mr. Simon, I have some difficulty in determining: but they are the only objects I have seen which correspond at all closely with his description ; unless, indeed, it were possible to suppose, as Dr. Johnson appears to hint, that he may have mistaken the normal disposition of the tubuli for a cystic structure.

" However this may be, I am satisfied that the vesicles above described are exceptional productions, and by no means invariably connected, as Mr. Simon describes his vesicles to be, with the progress of the desquamative degeneration. They are seen in comparatively few cases : on referring to four, of which I have drawings or memoranda, I find two to have been congested and waxy kidneys, with slight exudation, one to have been a soft and desquamating kidney, also with slight exudation, and one a granular kidney with numerous cysts, from the size of a pea to that of a hazel-nut. On the other hand, I have examined organs in every stage of desquamative disease without finding these bodies, the production of which cannot therefore be an essential step in the degeneration and atrophy of kidneys so affected.

" The origin and progress of these vesicles is very obscure. It is not improbable that, as Mr. Simon asserts, they are transformed into the larger cysts visible to the naked eye : though I confess that I have not been able to trace the intermediate steps of their progress in a satisfactory manner. On the other hand, their origin from extravasated epithelial cells seems exceedingly improbable ; indeed I have already stated, that I do not think the epithelium ever becomes extravasated. Moreover, the vesicles in question have all the appearance of being formed *within* the tubes, although they afterwards become separated from them.

" From the occasional appearances of alternate distention and constriction presented by the tubes when undergoing obliteration, I am induced to believe that cysts may be formed by the occlusion and isolation of portions of tube which have not yet lost their power of secretion. Whether the vesicles in question are formed in this way, can only be determined by close and repeated observation : and I have not been able to obtain demonstrative evidence on this point.

" The larger cysts in the kidney present very strong evidence of being formed in connection with the secreting membrane. In one instance I found their inner surface to be lined at some points with tessellated epithelium, in the form of pentagonal or hexagonal flattened cells, with circular nuclei ; in another case there were oval nuclei without any distinct cells, and a large number of free oil-globules of considerable size. The existence of oil in these cysts has also been observed by Dr. Johnson. Other products of secretion are also occasionally found. On one occasion I found several cysts in a kidney, otherwise healthy in appearance, which contained a turbid ochrey-coloured liquid, presenting under the microscope numerous minute crystals of uric acid. Mr. Simon mentions having found on two occasions xanthic oxyde in considerable proportion. I have more than once observed them to contain blood in large quantity; and I have likewise found them full of a matter like stiff glue.

" The occurrence of cysts in kidneys presenting a generally healthy structure is so frequent, as to lead to the idea that they must be in such cases the result of disease which has been arrested before any considerable disorganisation has taken place. Many of the cases of partial atrophy of the kidneys figured by Rayer are probably due to the rupture or obliteration of these cysts.

" Before leaving the subject of cyst-formation I may state, that in one instance I have observed the Malpighian capsules to be occupied by distinct cysts.*

" *Dilatation and Thickening of the Tubes.*—This condition, although by no means a very frequent one, is important as being characteristic, so far as I have observed, of the extreme stage of what I have called the ' waxy degeneration.' I have scarcely ever seen it unaccompanied by entire obliteration of the vessels, and by enlargement and increased density of the kidney. The organ has the dense resistant feeling of fibro-cartilage, and both cortical and tubular portions have the light yellow colour, and the appearances described above as those of the waxy degeneration in its last stage. The striæ of the pyramids appear to radiate indefinitely towards the surface, and meet the cortical substance in digitations, instead of being marked off by a sharp semicircular line, as occurs in the healthy kidney. When examined with a simple lens, or even the naked eye, the pyramidal striæ are seen to pursue an unusually sinuous course: this is peculiarly the case where they pass into the cortical substance. Moreover, the pyramids are unusually broad at the bases; and the length of the straggling digitations is sometimes so great, that I have measured fully an inch and a half between the extreme end of the striæ and the corresponding papilla. Nevertheless, the cortical substance is not usually diminished in quantity, being developed to a great extent between the pyramids.

" This condition I have ascertained to proceed from dilatation and thickening of the tubuli uriniferi throughout the organ. The dilated tubes are usually twisted and varicose, as may be seen by inspecting a section of the pyramids with a low power. When examined with a higher power, the section presents an appearance very similar to some tumours (of the fibrous or fibro-cystic kinds); viz. a number of compressed areolæ, enclosed by fibrous tissue, and presenting an appearance of irregular concentric rings, of various distinctness, (an effect apparently due to the peculiar refraction of light by the thickened membrane). The nuclei are obscured or invisible, owing to the thickness of the intervening wall, but nevertheless exist in considerable numbers. The Malpighian bodies and capillaries are usually obliterated. The kidney has in fact become, like the tumours whose structure it resembles, a true non-vascular texture.

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* *Obs.* In one case of cystic disease of the kidneys which fell under the notice of Mr. Quekett, the formation of the cysts evidently commenced in the corpora Malpighiana beneath the capillary plexus.— A. H. H.

" The explanation of the peculiar extension of the pyramidal striæ towards the surface in these cases, is to be found in the fact, that even in the normal condition the convoluted tubuli have a general disposition from the bases of the pyramids towards the surface, in the direction of the striæ of the cones. This is evident from the facility with which the gland tears in that direction; although in the normal state this disposition is masked by that of the vessels, which, passing in strait lines through the cones, break into a complicated network of capillaries at the bases of the pyramids. In the present lesion, the vessels having disappeared, and the course of tubes being strongly marked, their disposition towards the surface becomes manifest, and the abrupt line of demarcation between the cortical and pyramidal substance, caused by the presence of the vessels, is obliterated."

CONCLUSION.

With the view of enabling the reader to place the foregoing observations in relation with the descriptions found in systematic pathological works, Dr. Gairdner subjoins the following short remarks on the principal physical characters usually ascribed to diseased kidneys.

"*Increase of Size and Weight: Hypertrophy.* — Enlargement of the kidney occurs chiefly in consequence of three conditions: — 1st. from sanguineous engorgement; 2d. from distention of the tubes by secretion or exudation; 3d. from permanent dilatation and thickening of the tubes. Of all these causes, the second is by far the most common. The last is characteristic of the waxy degeneration formerly described.

"The quantity of liquid in the tubes is, at all times, subject to so much variation, that it is difficult to say what amount of increase of weight may be thereby occasioned without the existence of any positively morbid condition. It is not very uncommon to find kidneys otherwise not differing from the healthy standard, about double the usual weight, or between seven and eight ounces each. I have more than once found them to weigh nine ounces each, with very slight marks of disease. When the weight much exceeds this, it is probable it arises from the rare combination of vascular and tubular engorgement.

"In kidneys containing oleo-albuminous exudation, the greatest increase of size is attained, when the exudation is universal, and unaccompanied by desquamation.

"Cystic degeneration of the kidneys, dilatation of the pelvis and ureters (*Hydronéphrose*, Rayer), &c., also give rise to great increase of size and weight.

"*Diminution of Size and Weight: Atrophy.*—This condition sometimes occurs to a certain extent, in emaciated subjects, without any disorganisation, owing to the diminished activity of secretion. More frequently, however, it is the result of separation of the epithelium, followed by contraction and obliteration of the tubular structure.

"Atrophy, from this cause, is liable to supervene in all other varieties of renal lesion, except the waxy degeneration, which appears to lead to a permanently hypertrophied condition of the organ. In kidneys enlarged from exudation, the occurrence of desquamation and its consequences is frequent; and the diminution of size in such cases is often not followed by a return to the natural condition, but by permanent atrophy.

"The course of all disorganising diseases of the kidney is to produce first, enlargement, and then contraction of the organ. In the extreme stages of the atrophy which results from exudation, exudation is often nearly absent. When exudation, therefore, even in very sparing quantity, accompanies a contracted condition of the kidney, there is a probability that it has been abundant at some former period.

"*Irregularities of Surface: Tuberculated and Granulated Kidneys.*—The smoothness of the surface in the kidney is destroyed either by unequal dilatation or unequal contraction of the tubuli of the cortical substance. The former takes place in the waxy degeneration; the latter, in the desquamative processes.

"The most frequent irregularities of surface are formed in connection with the granulations of Bright. These are invariably formed when exudation is deposited in kidneys tending to the desquamative lesion; and, as this runs its usual course, the granulations become prominent from the destruction of the tubes around them. An extreme degree of the irregularities thus produced constitutes the tuberculated kidney.

"The puckering and partial atrophy occasionally seen in kidneys, otherwise not morbid, or comparatively slightly diseased, are probably, in many instances, the result of the obliteration of cysts.

"The more remarkable changes in colour and consistence are described very fully in many parts of the preceding memoir."

On reviewing the whole of the preceding observations, Dr. Gairdner is induced to regard the following conclusions as especially important in relation to the pathology of renal diseases:—

"1. By far the greater part of the pathological lesions of the kidney arise from, or are connected with, the exudation of oleo-albuminous granules into the interior of the tubes and epithelial cells.

"2. The oleo-albuminous exudation is, probably, often preceded, and, certainly, occasionally accompanied, by vascular congestion; but when the quantity of exudation is considerable, more or less complete depletion of the vascular system invariably occurs. This is a secondary result of the obstruction of the *tubuli uriniferi.*

"3. The oleo-albuminous exudation occurs in two chief forms: viz. *first*, universal infiltration of the tubes throughout the organ; and, *second* infiltration of peculiar sets of tubules: the rest remaining free, or nearly so. In the latter mode arise the granulations of Bright.

"4. There is no essential anatomical difference between the exudations in the kidney, which are the result of chronic processes, and those which have been considered as the result of inflammation.

"5. The capillary vessels of the kidney are subject to spontaneous obliteration (unaccompanied, in the first instance, by any visible lesion of the tubes), giving rise to the peculiar affection which I have called the *waxy degeneration.* This obliteration of the vessels is probably, in all cases, preceded by a stage of congestion.

"6. The consequence of the waxy degeneration is thickening and varicose dilatation of the tubuli throughout the organ.

".7. The tubes of the kidney are subject to contraction and obliteration, in consequence of the desquamation of their epithelium; a condition resulting in atrophy, and complete disorganisation of the organ.

"8. The desquamation of the epithelium occurs very frequently in all the other diseased conditions of the kidney. When sufficiently long-continued and extensive, it produces contraction, and this indifferently, whether exudation be present or not. It is sometimes accompanied by vascular congestion in every stage of its progress.

"9. The earlier stages of the exudations can only be discovered by means of the microscope. The progress of the waxy degeneration, on the contrary, is best traced by the unaided eye. The desquamation of the epithelium is only to be discovered with certainty by means of the microscope, and is particularly apt to escape attention, under all circumstances, if the *kidney* only, and not the *urine*, be looked to. It results that careful investigation, both by the microscope and the naked eye, both of the kidney after death and the urine during life, are indispensable, to enable the pathologist to determine with exactitude the presence or absence of disease."

I have been induced to dwell thus largely on the microscopic pathology of the kidney: first, on account of the great importance and interest attached to the lesions of that organ; secondly, from the great number of interesting facts which the microscope has already brought to light in reference to its pathology; and, thirdly, in the hope of inducing other observers to follow out more completely the enquiry which has already led to such successful and striking results.

TESTIS.

The testis, the last of the tubular glands in the human subject, agrees more closely in structure with the sudoriferous and ceruminous glands than with the kidney; there being this in common between the three first-mentioned, viz., that the tubes, of which they are principally constituted, are convoluted, and are not enclosed in a dense framework of fibro-elastic tissue, as is the case with those of the kidney.

The testis is invested by a tunic of white fibrous tissue; this sends down, into the substance of the gland, numerous dissepiments, which divide the tubes of which it is composed into parcels, each of which may be called a lobe.

The tubes of the testes are remarkable for their large size, great tortuosity, and exceeding and ready extensibility. (See Plate LX. *figs.* 1. 4.)

When viewed as opaque objects, the tubes appear of a delicate and semi-transparent whiteness; and, when seen by transmitted light, they are almost black; this arises from the fact of the interception of the luminous rays by the cells contained within the tubes.

The membrane of the tubes is totally distinct from that of most other tubular glands; it is very thick and fibrous, being constituted of a well-marked form of nucleated fibro-elastic tissue. (See Plate LX. *fig.* 4.)

The constitution of the tubes of elastic tissue explains satisfactorily their ready extensibility and variable diameter; this variation, in specimens prepared for microscopic examination, is very obvious, and arises from the displacement of contained cells, occasioned by unequal external pressure; where these cells are accumulated in the greatest number, there the tubes are thickest; and where there are but few cells, or even where the tubes are destitute of cells, they are thinnest, and frequently even entirely collapsed.

These facts show that the tubes are highly expansive; and there is no doubt that their diameter varies, during life, in accordance with the amount of seminal fluid contained within the testis; this expansive property being especially designed to allow of the accumulation of that fluid within the semeniferous organ.

The tubes of the testis contain a vast number of granular cells of various sizes (see Plate LX. *fig.* 4.), some being several times larger than others, especially in the testis of the adult. Most of these cells contain but a single nucleus; in others, however, and these the larger cells, there are as many as from two to seven, or even more, distinct nuclei. (See Plate XVI. *fig.* 1.)

In the testes of a child, the granular cells present great uniformity of size, and contain, for the most part, but a single nucleus. These cells, as in other tubular glands, form a regular epithelium on the walls of the tubes, the central channel being free; this arrangement is very evident in the tubes of immature testes; but far less so in those of the adult organ; the manipulation to which the latter are subject, when being prepared for microscopical observation, readily displacing the cells.

It is in these cells, according to the observations of numerous observers, that the spermatozoa are developed. For further particulars on the development of the spermatic animalcules, see the article "Semen."

The tubes of the testes are loosely bound together by bands of fibrous tissue; it is this tissue which contains the tortuous blood-vessels with which this organ is so copiously supplied.

That the tubes are not furnished with a distinct external envelope, like those belonging to the kidney, is proved by the fact that they admit readily of being separated from each other, as also of being drawn out to a great length: this last circumstance shows the extent to which the tubes are convoluted, the few anastomoses which take place between them, and their extraordinary elasticity.

VASCULAR GLANDS.

The vascular glands all agree with each other in the absence of excretory ducts or channels for the discharge of their secretion, a deficiency which involves as a necessary consequence the reception of the secreted fluids by the blood-vessels.

From the differences in the size and structure of these several glands, it is very doubtful whether any other resemblance besides that just pointed out exist between them, and it is most probable that each has a separate purpose to fulfil in the animal economy.

THYMUS.

The thymus, although usually spoken of and described as a single organ, is in reality double, and consists of two distinct glands united to each other in the middle line by cellular tissue only.

Each separate adult thymus is constituted of numerous, probably some hundred follicles, which vary in size from a pin's head to, in some cases, that of a pea, and the walls of which are made up of mixed fibrous tissue.

These follicles are usually more or less rounded, but sometimes polygonal in shape from pressure; they are loosely held together by fibrous tissue, and by the blood-vessels which supply them; they each contain in their interior a cavity which is more or less filled with a milky fluid. (See Plate LXI. *fig.* 8.)

Several of these follicles open into each other and into a common receptacle or "pouch," and this last again opens into the internal cavity of the gland, the face of which is thickly studded with similar openings.

On its exterior each follicle may be seen, even without injection, to be invested with a very beautiful plexus of blood-vessels, represented in Plate LXI. *fig.* 8.

When unravelled by the removal of the interlobular cellular tissue, the whole gland is seen to consist of a straight tube, with the follicles arranged around it in a spiral manner.

The central cavity, "reservoir of thymus," is lined by a delicate mucous membrane, which is raised into ridges by a layer of ligamentous bands situate beneath it; these proceed in various directions, and encircle the apertures of the pouches: their use is to keep the lobules together, and to prevent the injurious distention of the cavity.

The whole organ is enclosed in a dense capsule of fibrous tissue, the blood-vessels contained in which are remarkable for their disposition in threes, an arrangement which is not uncommon in the capsular investments of glands. (See Plate LXI. *fig.* 7.)

The "milky fluid" contained in the follicles and reservoir is made up, to a great extent, of an immense number of granular nuclei, as well as numerous cells of large size, which do not appear hitherto to have been either described or figured in a satisfactory manner, and which are probably to be regarded in the light of parent cells. (See Plate LXI. *fig.* 10.)

Many of these cells contain several granular nuclei, each of which is surrounded by one or more concentric lamellæ; they thus resemble the cartilage cells found in the intervertebral substance, and also certain species of *Microcystis*, a genus of Freshwater Algæ.

Mr. Simon, in his "Prize Essay," makes the following observations on the above-described cells: — "In specimens taken from animals past that period of life when the thymus is most active, I have found cells in which these dotted corpuscles occupied the relation of nuclei. The cells are at first little larger than the corpuscles themselves, and contain a perfectly pellucid material; but as they grow, their contents become molecular, and they develope themselves into perfect fat-cells, which lie in the cavities of the glands, and in some instances completely fill them. During the period in which these cells are being developed, the application of acetic acid to the preparation as it lies under the microscope shows them to have great affinity to embryonic cells; for the acid dissolves the cell-membrane completely away, and leaves the nucleus of the cell (the dotted corpuscle) unaffected by its action."

Lining each follicle, Mr. Simon has detected a delicate and homogeneous structure, which he has termed the "*limitary membrane:*" this structure is identical with the basement membrane of Bowman, and is probably common to all glands, especially the follicular ones.

Mr. Simon has likewise described a lobular arrangement of the follicles. The structure of the gland resolves itself, he says, "into masses ranged round an axis. Each mass constitutes a sort of cone of glandular substance, its apex pointing to the axis or mesial line of the gland; its base directed to the surface, where it presents innumerable vesicles; while its intermediate part contains those successive branchings of the follicle which terminate superficially in the vesicular form."

THYROID GLAND.

The anatomy of this gland is best studied in a specimen which has undergone a slight enlargement of its several parts: a portion of such a gland, when viewed with the inch object-glass, bears so close are semblance to a mass of fat, that, except by a practised microscopist, it would be impossible to distinguish it therefrom with such a low power; even when viewed with the half-inch, the illusion would scarcely be dispelled, and it is only on the application of the quarter-inch glass, that misgivings would begin to be entertained in reference to its identity with fat.

The resemblance borne by a portion of thyroid gland thus slightly enlarged by disease to a mass of fat, arises from the form of the vesicles or closed cells of which the gland is composed, and from the manner in which they reflect the light, the centre of each vesicle being clear and bright, and the circumference dark and almost black; here, however, the resemblance ceases, as the thyroid vesicles are most satisfactorily distinguished from fat globules by their larger size, the fibrous texture of their parieties, and the nature of their contents.

Such is the general character and appearance of a portion of thyroid examined microscopically ; the entire gland, however, consists of two lobes, which are placed one on each side of the trachea, and which are connected with each other by a narrow slip or isthmus of the gland, and these lobes are further divisible into numerous lobules, many hundreds to each lobe. Now it is these lobules which, so far as the descriptions hitherto given of this gland are to be understood, have been regarded and described as the membranous cavities of the thyroid (see Plate LXI. *fig.* 1.), the true and ultimate cellular structure being in general overlooked.

Thus the lobules are further divisible, each into many small cavities, the ultimate divisions of which the gland is susceptible. (See Plate LXI. *figs.* 2, 3, 4, 5.) These in the slightly enlarged gland are circular, and comparable to fat vesicles (see Plate LXI. *figs.* 2, 3.); but in the gland in its normal state, they are compressed and angular, being also very liable to be altogether overlooked, their size and form being indicated only by certain light-coloured spaces traversing the lobule. (See Plate LXI. *fig.* 5.)

Over the surface of each lobule, the blood-vessels form a plexus, from which branches proceed inwards, encircling the vesicles much in the same way as the blood-vessels do the fat corpuscles. (See Plate LXI. *fig.* 1.)

The cavity of each vesicle is perfectly distinct, and does not communicate with that of any other of the vesicles by which it is surrounded: the fibrous tissue, however, of which its walls are so evidently composed (see Plate LXI. *fig.* 4.) does communicate with and run into that of the neighbouring vesicles, at certain points, however, only. These fibres may frequently be traced from the wall of one cell into that of another; and it is this fibrous union of the vesicles which renders it impossible completely to isolate any one of the cells, and accounts for the fact, that when the vesicles are broken up with needles, they are entirely reduced to fibrous tissue.

The contents of the vesicles consist of a fluid, containing numerous granular nuclei of a rounded or oval form, as well as of a few perfect cells, two or three times larger than the nuclei, and the granules contained in which are very large, presenting an oily aspect; between these two extremes of size, other cells intermediate are met with: the larger are evidently parent cells. (See Plate LXI. *figs.* 9. and 4.)

The fluid of the vesicles contains a good deal of oil, which when the gland is slightly decomposed, is apt to collect in them in the form of one or two large circular discs.

The increase in the size of the gland in goitre is due to an increased development of the vesicles and of their contents.

It is evident that each vesicle contains all the elements of the gland, and that the entire organ is made up of an assemblage of many thousands of such vesicles or glands. (See Plate LXI. *fig.* 2.)

SUPRA-RENAL CAPSULES.

The supra-renal capsule bears some resemblance in structure to the kidney, being divisible like it into a cortical and medullary substance.

It is made up of numerous simple and cylindrical tubes closed at both ends, and formed of structureless basement membrane; these tubes are disposed in a vertical manner, one extremity forming the surface of the organ, and the other extending in an opposite direction, as far as the inner cavities or lacunæ situated in the centre of each supra-renal capsule. (See Plate LXII. *fig.* 3 *a.*)

These tubes enclose elements of three kinds; first, innumerable circular particles or molecules, which reflect the light strongly, and which are of an oily nature; of these the greater part is free in the tubes, but a lesser proportion is enclosed in certain of the cells which are met with in the tubes; second, granular nuclei in large quantities; and, third, parent cells of considerable size, containing each several nuclei intermingled with, and in part very frequently obscured by a considerable number of the bright molecules previously referred to. These parent cells do not appear to have been hitherto characterised with any degree of precision. (See Plate LXII. *fig.* 3 *b.*)

The differences between the cortical and medullary portions of the supra-renal capsule, depend principally upon the irregular disposition of the tubes in the latter, the plexiform arrangement of the vessels, and on the presence of numerous parent cells containing more or less of colouring matter in their interior. It is these cells which impart to sections of the gland the dotted appearance so commonly observed in its medullary portion. (See Plate LXII. *fig.* 3.)

The vascular distribution in the supra-renal is very simple. On the surface of the organ we have a very beautiful plexus of capillaries, the pentagonal and hexagonal meshes of which lie in the intervals between the extremities of the tubes; in the tubular part the vessels, both veins and arteries run in straight lines between the tubules, terminating, on the one hand, in the plexus on the surface, and, on the other, in the central plexus. (See Plate LXII. *fig.* 1. 5.)

The supra-renal is an organ which varies greatly in different subjects; in some the proportion of granules is much greater than in others; in others again, the central lacunæ are occupied with a whitish-looking substance, which, on examination, is found to consist of granular nuclei arranged in irregular masses, but in which sometimes we can detect a tubular disposition: in these cases we encounter from without inwards, three substances; cortical, medullary, and then lastly, the central substance just described.

The capsule of the supra-renal is often laden with fat, which totally obscures the plexus on the surface of the organ.

The parent cells, when filled with oily molecules, bear a close resemblance to the cells of a sebaceous gland, between which and the supra-renal capsule one would hence be disposed to suspect a degree of affinity.

SPLEEN.

The spleen consists of a fibro-elastic capsule which sends down from its inner surface septa, which penetrate the organ in all directions, and divide it into compartments; of an immense assemblage of blood-vessels which compose its chief substance, and which impart to it the character and appearance of an erectile tissue; and, thirdly and lastly, of a small quantity of secreting structure, consisting of nuclei only, and which appears to lie in the intervals between the blood-vessels. (See Plate LXII. *fig.* 2.)

The above comprehends all that can be readily made out of structure in the spleen: the examination, however, of this organ is by no means satisfactory or easy on account of the impossibility of fully injecting it, a difficulty which arises from causes but imperfectly understood.

Dr. Julian Evans, however, describes a very elaborate structure and arrangement of the tissues in the spleen, as will be seen from the perusal of the following abstract of his paper taken from the 3d edition of Carpenter's "Principles of Human Physiology."

"According to the account of Dr. Julian Evans *, whose researches appear to have been more successful than those of any other anatomist, the spleen essentially consists of a fibrous membrane, which constitutes its exterior envelope, and which sends prolongations in all directions across its interior, so as to divide it into a number of minute cavities or lacunæ of irregular form. These *splenic lacunæ* communicate freely with each other, and with the splenic vein; and they are lined by a continuation of the lining membrane of the latter, which is so reflected upon itself, as to leave oval or circular foramina by which each lacuna opens into others, or into the splenic vein. The lacunæ, whose usual diameter is estimated by Dr. E. at from half to one third of a line, are generally traversed by filaments of elastic tissue, imbedded in which a small artery and vein may be frequently observed; over these filaments, the lining membrane is reflected in folds; and, in this manner, each lacuna is incompletely divided into two or more smaller compartments. There is no direct communication between the splenic artery and the interior of the lacunæ; but its branches are distributed through the intercellular parenchyma (which will be presently described): and the small veins which collect the blood from the capillaries of the organ, convey it into these cavities, from which it is conveyed away by the splenic vein. The lacunæ may be readily injected from the splenic vein with either air or liquid, provided they are not filled with coagulated blood; and they are so distensible, that the organ may be made to dilate to many times its original size with very little force. This is especially the case in the spleen of the Herbivora; for the spleen of a sheep weighing four ounces, may be easily made to contain thirty ounces of water. That of man, however, is less capable of this kind of enlargement. According to Dr. Evans, the lacunæ of the spleen never contain any thing but blood; and he notices that a frequent condition of the human spleen after death, which is sometimes described as a morbid appearance, consists in the filling of the lacunæ with firmly coagulated blood, which gives a granular appearance to the organ.

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* Lancet, April 6th, 1844.

"The partitions between the lacunæ are formed, not only by the membranes already mentioned, but by the peculiar parenchyma of the spleen; which constitutes a larger part of the organ in man, than in the Herbivorous Mammalia. It presents a half-fluid appearance to the eye; but when an attempt is made to tear it, considerable resistance is experienced, in consequence of its being intersected by what appear to be minute fibres. When a small portion of it is pressed, a liquid is separated; which is that commonly known as the Liquor Lienis, or splenic blood; which is usually described (but erroneously, according to Dr. E.) as filling the lacunæ of the spleen. This liquid, when diluted with serum and examined under the microscope, is found to contain two kinds of corpuscles, — one sort being apparently identical with ordinary blood-corpuscles, — and the other with the globules characteristic of the lymph and abundant in the lymphatic glands. The remaining fibrous substance consists entirely of capillary blood-vessels and lymphatics, with minute corpuscles, much smaller than blood-corpuscles, varying in size from about 1-6000th to 1-7000th of an inch, of spherical form, and usually corrugated on the surface. These lie in great numbers in the meshes of the sanguiferous capillaries; and the minute lymphatics are described by Dr. E. as connected with the splenic corpuscles, and apparently arising from them. Lying in the midst of the parenchyma, are found a large number of bodies, of about a third of a line in diameter, which are evidently in close connection with the vascular system; these have been long known as the Malpighian bodies of the spleen, after the name of their discoverer; but since his time, their existence has been denied, or other appearances have been mistaken for them.

"According to Dr. E., they in all respects resemble the mesenteric, or lymphatic glands in miniature, consisting as they do of convoluted masses of blood-vessels and lymphatics, united together by elastic tissue, so as to possess considerable firmness: and they further correspond with them in this — that the lymph they contain, which was quite transparent in their afferent lymphatics, now becomes somewhat milky, from containing a large number of lymph globules."

Dr. Hanfield Jones has noticed the occurrence of certain peculiar corpuscles in the spleen of various animals, including that of fishes, mammals, and man; these corpuscles he describes as follows *: —

"In the spleens of various animals there may often be seen a number of minute corpuscles of a yellow colour, varying from a dark to a pale hue; they occur sometimes singly, but mostly in groups, which I have sometimes thought were

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* Medical Gazette, 1847, p. 141.

aggregated, especially along the larger blood canals. These groups are made up of corpuscles of very various size; they do not appear to have any special connexion with the surrounding substance, which occasionally, however, has a decided yellow tinge.

"In the animal series, I have found these corpuscles most highly developed in fishes. In the human subject they are rarely to be found. I have, however, observed them distinctly in six instances, in one of which they were very large and numerous. In most of the cases in which they were found there had been considerable interruption to the respiratory process. The spleen was generally much enlarged, soft, and of rather a pale colour, quite an opposite condition to that often observed in cases of 'Bright's disease,' where the organ is found small and contracted: in such spleens I have never found any of the yellow corpuscles."

For a description of the Pineal and Pituitary glands, placed in the classification under the heading "Vascular Glands," the reader is referred to the Appendix.

ABSORBENT GLANDS.

The absorbent system of vessels is divisible into lacteals and lymphatics, the glands attached to the former being called mesenteric, and those to the latter, lymphatic glands.

The lacteal absorbents commence in a plexiform manner in the villi of the small intestines, while the lymphatic absorbents originate all over the body, in the same manner, in each of the several tissues and organs of which it is composed: they are minute, delicate, and transparent vessels, remarkable for their uniformity of size, a knotted appearance due to the presence of numerous valves, the dichotomous divisions which occur in their course, and their separation into several branches immediately before entering a gland.*

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* See the Article "Lymphatic System," by Mr. Lane, in the Cyclopædia of Anatomy and Physiology.

In the mesentery, the lacteals become variously coiled and knotted, these aggregations of coils, together with fibrous tissue and blood-vessels, forming the mesenteric glands; the lymphatic glands have a similar structure and origin, being placed in certain determinate regions of the human body.

The lymphatics which enter a gland, or the afferent lymphatics, vary in number from two to six; they divide at a short distance from the gland into several smaller vessels, and enter it by one of the flattened surfaces: while those which leave it, or the efferent lymphatics, escape from the gland on the opposite, but not unfrequently on the same surface; they also consist, at their junction with the gland, of several small vessels, which unite after a course of a few lines and form from one to three trunks, often twice as large as the afferent lymphatics.

The afferent lacteals and lymphatics, as they enter the gland, become somewhat dilated; and the epithelium, in place of forming a single layer of flattened cells firmly adherent to the walls of the tubes, consists of several layers of rounded and glandular cells, which are very readily displaced.

These cells are doubtless more or less concerned in the elaboration of the fibrin of the chyle; and there is much reason to believe that from time to time the more mature cells become detached from the walls of the lacteals, and are conveyed along with the chyle into the blood, where they become the white or granular corpuscles of that fluid.

Such is a very brief outline of the minute anatomy of the mesenteric and lymphatic glands.

This is probably the most fit place to introduce a few remarks on the structure of the villi themselves, the chief agents in the absorption of the chyme, and the parts in which the lacteals themselves take their origin.

The Villi of the Intestines.

The villi exist in the whole extent of the small intestines, but it is in the lower part of the duodenum and the whole of the jejunum that they are best developed, and the lacteals most readily detected.

Several distinct structures have to be noticed and described entering into the constitution of each villus: these are the epithelium resting upon the outer surface of the villus, the basement membrane, the intra-villous nuclear contents, the fatty intra-villous contents, the blood-vessels of the villus and its lacteals; these several parts will be described in the order of their enumeration.

The *epithelium* investing the villi (see Plate LII. *fig.* 1.), is of the conoidal variety already fully described and figured. It not merely clothes the villi from base to summit; but also the interspaces between them, as well as the numerous follicles of Lieberkuhn, situated in the whole length of the small intestines.

According to the observations of Professor Goodsir, this epithelium is shed on each recurrence of the process of chymefication, the cells first absorbing the partially elaborated chyme, effecting a further elaboration of it, and finally becoming ruptured and dissolved, set free the fluid absorbed, at the same time adding their own substance to augment its amount and nutritive qualities.

The accuracy of this view is in the main admitted by most observers; Professor Weber and Dr. Jones, however, do not consider that the shedding of the epithelium is *necessary* to enable the villi to perform their function; and the latter observer makes the following remarks on this point: "I have certainly seen the villi *clad with their epithelium* when the lacteals have seemed to be every where filled with chyle: however, I think there can be little doubt that, when the absorbing process is most actively performed, the villus does throw off its protecting covering; certainly, this is the case in a great number of instances." *

The *basement membrane* of the villi is a continuation of that of the general surface of the mucous membrane, and is, as far as has yet been ascertained, perfectly structureless.

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* Medical Gazette, Nov. 17th, 1848.

The *granular*, or, more correctly speaking, the *nuclear*, *contents* of the villi have been noticed by several observers (See Plate LII. *fig.* 1, 2.). Dr. Jones, however, in the communication already referred to, has pointed out the fact that the nuclear and granular contents of one villus are continuous with those of another, and that the granules and nuclei form a continuous stratum lying beneath the basement membrane, extending not merely from villus to villus, but also throughout the large intestines, where it is very easily seen in the spaces between the follicles.

Professor Goodsir has described these granular nuclei, as enlarging during the process of absorption, and as forming a number of enlarged and very evident cells at the apex of the villus. These supposed cells, however, are nothing more than *oil drops*, usually of a brown colour, and of various sizes. (See Plate LII. *fig.* 2.) At this conclusion I arrived many months since, and gave a figure of these oil drops in the villi in the 13th Part of the Microscopic Anatomy, published in April 1848; and I am glad that Dr. Jones entertains a similar opinion of their nature. I may at the same time remark, that the cells delineated in the original figure given by Professor Goodsir, have all the characters of oil drops, being round, smooth, and reflecting the light strongly.

The use of these oil drops in the villi is by no means evident: they are formed, in all probability, by the cohesion of the smaller oily granules which are scattered throughout the villi during the process of absorption, and which contribute so greatly to their opacity; in the end they are most probably absorbed by the lacteals.

Notwithstanding, however, the non-existence of the peculiar cells described by Professor Goodsir, the leading idea of that observer of the elaboration of the chyme within the villus is still correct, the agents in this work being the nuclei already described.

The presence of these nuclei throughout the whole length of the villus seems to point to the inference that it is not the apex only which absorbs.

Each villus is copiously supplied with blood-vessels; an *artery* ascends one side of the villus, a *vein* descends along the opposite side, and between these two principal vessels a very complicated and beautiful *plexus of capillaries* is extended. (See Plate LI. *figs*. 3, 4, 5.).

The *lacteals* are described as originating in the villi in a plexiform manner.

In the rabbit I have observed a very curious construction of the villi, their surfaces being studded with numerous mucous follicles; the portion of intestine exhibiting these characters was most probably taken from near the junction of the large and small intestines; and I have little doubt but that the villi of the human intestine, in a corresponding position, would exhibit the same combination of the structural peculiarities of both small and large intestines.

The anatomical characters of the mucous membrane of the stomach, and large intestines, have already been described. (See page 393. *et seq.*)

ART. XXII. ORGANS OF THE SENSES.

TOUCH.

Papillary Structure of the Skin.

THE sense of Touch is the simplest as well as the most universally diffused of the senses, it not merely extending over every portion of the external surface of the body, but also over certain of the internal mucous surfaces, as those of part of the mouth, nose, &c.

Over the general surface of the body this sense exists under the form of common sensation; and it is only in certain parts, as on the palmar and plantar surfaces of the hands and feet, that it becomes so highly developed as to assume the importance of a distinct sense, and to deserve the name of Touch.

This sense has its seat in the papillary structure of the skin, and the degree of the development of this structure, as shown by the size and number of the papillæ, is always proportionate to the degree of perfection of the sense: thus the papillæ over the general surface of the body are much less numerous and less perfect in form than they are in the palms of the hands and soles of the feet.

The papillæ in the natural state are of course invested by the epidermis, which indeed conceals them to a great extent from view; this requires to be removed by maceration before their form, size, and arrangement can be clearly ascertained.

After the removal of the epidermis, it will be seen that the papillæ on the general surfaces of the body do not follow any definite arrangement, but are scattered here and there without apparent order, more or less thickly according to the degree in which the part of the integument upon which they are seated is endowed with sensation, but every where they are less numerous than on the palmar and plantar surfaces of the hands and feet. (See Plate LXIII. *fig.* 4.)

On the palms of the hands and soles of the feet, the papillæ are arranged, as may be seen with the naked eye, in lines or ridges, each ridge being made up of two rows of papillæ in single file, and between each pair of which a further line of separation may be traced: such is the general disposition of the papillæ in each ridge; the ducts of the sudoriferous glands pass through its centre, and between the rows of papillæ, the number of these glands and ducts to that of the papillæ being in the proportion of one to four. (See Plate LXIII. *fig.* 3.)

The arrangement just described can be well seen on the palms of the hands by the aid of a lens, even while the epidermis is still attached to the cutis; the ridges are seen to be disposed here and there in beautiful curves, some abruptly coming to a termination, and others dividing into two distinct ridges, this disposition enabling them to adapt themselves more accurately to the varying nature of the surface over which they are extended: along the middle of each ridge, the apertures of the numerous sudoriferous glands may be seen for the most part crossed in the direction of the diameter of the ridge by a faint groove, which indicates the line of separation of the papillæ into pairs. (See Plate LXIII. *fig.* 1.)

Each papilla appears to consist of a prolongation of basement membrane, and contains in its interior granular and nuclear contents and a single looped blood-vessel, (see Plate LXIII. *figs.* 3. 7.): these points of structure are all made out readily enough; the chief difficulty consists in the determination of the manner in which the nerve filaments, with which the papillæ are undoubtedly supplied, terminate in them. On this subject, Messrs. Todd and Bowman* have the following observations: — "In regard to the presence of nerves in the papillæ themselves, we can affirm that we have distinctly traced solitary tubules ascending among the other tissues of the papillæ about half way to their summits, but then becoming lost to sight, either by simply ending, or else by losing the white substance of Schwann, which alone enables us to distinguish them in such situations from other textures. Thin vertical sections of perfectly fresh specimens are essential for this investigation, and the observer should try upon them the several effects of acetic acid and solution of potass. In thus describing the nerves of the papillæ from our own observations, we do not deny the existence of true loop-like terminations as figured by so respectable an authority as Gerber; but neither do we feel entitled to assent to it. . . . We incline to the belief that the tubules, either entirely or in a great measure, lose the white substance when within the papillæ."

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* Physiological Anatomy, p. 412.

Messrs. Todd and Bowman further observe, in reference to the structure of the papillæ: — "Within the basement membrane it is difficult to distinguish any special tissue, except by artificial modes of preparation. A fibrous structure, however, is apparent, having a more or less vertical arrangement; and with the help of solution of potass, filaments of extreme delicacy, which seem to be of the elastic kind, are generally discoverable in it."

The blood-vessels of the papillæ consist of single loops; each of these is made up of an artery and a vein: the former, derived from the arterial plexus of the cutis, ascends the papilla on one side, and on reaching its summit gradually merges into the vein which descends along its opposite side, and terminates in the venous plexus of the cutis. In an injected preparation, and where the villi are large, the turn of the loop is seen to be very abrupt, the two vessels, the artery and the vein, coiling round each other, and resembling a piece of twine which has been bent upon itself and afterwards twisted in a spiral manner. This disposition of the vessels seems intended to delay somewhat the passage of the blood through the papillæ. (See Plate LXIII. *fig.* 7.)

The thickness of the epidermis which so closely invests the papillæ, does not appear to have any direct relation to the sense of touch: thus, over the general surface of the body, where this sense exists only as common sensation, the epidermis is very thin, while over the palmar surface of the hands it is very thick; the epidermis must not be too thick, however, even in this situation, as is shown by the fact, that where it has been greatly thickened by manual labour, touch is totally obscured.

The density of the epidermis in certain situations is evidently due to pressure, and may be explained by the fact that such pressure induces an increased determination of blood to the part, which is followed by increased nutrition and development. Between the sense of touch and the number of sudoriferous glands, there would appear to be a certain relation: thus on the palmar aspect of the hands, where this sense exists in its highest perfection, the number of sweat glands is very great.

The use of these glands in this situation in such increased numbers, may readily be conceived to be to keep the epidermis in a moist and flexible condition, whereby impressions would be more readily conveyed to the papillæ and more distinctly felt, the acuteness of the entire sense being thus greatly augmented.

The epidermis is very accurately adapted to the papillæ, so that when detached and viewed upon its under surface, it is seen to contain exact impressions of each and all of them; it is in this manner that their form, size, number, and arrangement are best studied, and it will then be noticed that, in all these particulars, considerable variations exist. (See Plate LXIII. *figs.* 5, 6.)

TASTE.

Papillary Structure of the Mucous Membrane of the Tongue.

The mucous membrane of the tongue, the principal if not the sole seat of the sense of taste, is divisible, like the skin, into a chorion, a papillary structure, and an epidermis or epithelium.

The chorion is a firm and tough membrane, formed of mixed fibrous tissue, and containing in its substance the blood-vessels and nerves, arranged in a plexiform manner, from which the papillæ are supplied: to its under surface the extremities of the muscular fibres of the muscles of the tongue are firmly attached; this arrangement imparts to the whole organ a considerable power of movement and of nice adaptation.

The papillary structure, which is the real seat of the sense of taste, is constituted of an immense number of papillæ, which occasion a somewhat flocculent appearance of the whole surface of the tongue.

The papillæ are divisible into simple and compound, and the latter again into filiform, fungiform, and calyciform; besides these several compound forms, however, others exist of no very definite shape, but approaching more or less closely in their characters to either the fungiform or calyciform papillæ.

The *simple* papillæ exist principally on the sides and under surface of the tongue, but also, though more sparingly, on its upper surface, as between the filiform papillæ, in the space around the base of each fungiform papilla, and for a short distance behind the calyciform papillæ, and to either side of them. (See Plate LXV. *fig.* 10.)

They vary somewhat in size, form, and structure in different situations; in general they are much pointed at their extremities: behind the calyciform papillæ they are obtuse and pyriform in shape, (see Plate LXV. *fig.* 11.) while on the under surface of the tongue their extremities are very frequently perforated, and they appear to serve the double purpose of a papilla and mucous follicle. (See Plate LXV. *fig.* 2.)

They each consist of, in addition to their epithelial investment, a layer of basement membrane, a single looped blood-vessel, filaments of nerves, and granular and nuclear contents. (See Plate LXV. *fig.* 6. and Plate LXVI. *fig.* 5.)

The *compound* papillæ are confined to the upper surface and edges of the tongue, and do not extend, except for a short distance at the sides, over the space bounded in front by the calyciform papillæ, and behind by the epiglottis.

This chain of papillæ forms the extreme boundary of the space over which the sense of taste extends, the surface behind it being smooth, non-papillary, and exhibiting numerous openings of mucous glands; thus then it would appear we have a true *gustatory region.*

Each compound papilla is made up of numerous simple papillæ, arranged differently in the case of the three forms of these already enumerated.

The *filiform* papillæ are by far the most numerous, being more than in the proportion of twenty to one; when freed from epithelium they are seen to be more or less cylindrical in form, and to consist of a variable number of simple papillæ from sixteen to twenty or more to each, arranged in a single circular series, forming the top and margin of the cylinder. (See Plate LXIV. *fig.* 3.) The sides of the simple papillæ are more or less united together, but the tips are free and pointed, some more so than others.

The length of the cylinder which each filiform papilla describes, the degree of acumination of the apices of the secondary papillæ, and the extent of these which is free, varies in accordance with the position of the papillæ on the tongue.

The circular disposition referred to is best seen in the papillæ placed near the tip and sides of the tongue, for in those situations the secondary papillæ are short, blunt, and nearly of equal lengths. (See Plate LXIV. *fig.* 3.) In the centre of the organ the simple or secondary papillæ are much longer, and more slender, so that they fall together and variously intermix with each other, and thus it is that the circular disposition in them is usually more or less concealed from view. (See Plate LXIV. *fig.* 4.)

This disposition of the secondary papillæ includes of course, as a consequence, a corresponding arrangement of the bloodvessels, (a single looped vessel proceeding to each), and of the nerve filaments, which are in like manner arranged in circles. (See Plate LXVI. *fig.* 4.)

The centre of each filiform papilla is hollowed out, and is to be regarded as a large mucous follicle, and thus the comparison of these papillæ to a cylinder is rendered almost complete. (See Plate LXIV. *fig.* 3.)

We shall presently see that the same circular arrangement extends to the filiform epithelial appendages hereafter to be described, and one of which corresponds to each secondary papilla.*

The *fungiform* papillæ are seated principally on the tip and sides of the tongue, at least they are most evident in those situations, and around each a space or shallow fossa, dotted with numerous simple papillæ, may be observed; they are distinguished from the filiform papillæ by which they are surrounded, by their form, being narrow at the base, and dilated near the summit, by being clothed all over with simple papillæ, which are usually a good deal compressed in form, and by the tenuity of the epithelium, destitute of filiform appendages, which covers them, and which allows of the blood in the vessels being seen through it. (See Plate LXIV. *fig.* 5.)

At the edges of the tongue, and at the sides behind the calyciform papillæ, compound papillæ exist, which bear some resemblance to the fungiform papillæ, of which they may be described as modifications; they differ from ordinary fungiform papillæ, however, in being sessile and simply rounded; in the form of the simple papillæ which clothes them, and which usually are not compressed, but swollen at the extremity, or pyriform. (See Plate LXV. *fig.* 11.)

The *calyciform* papillæ bound the true gustatory region posteriorly; they are seven or eight in number, and arranged in two rows, which meet behind in the foramen cæcum, and enclose a V-shaped space, the concavity of which looks forward.

They each consist of a depression or cup, out of which a large papilla, sometimes more or less adherent to the rim of the cup, arises, and the level of which it but little exceeds; the central papilla, as well as the sides and margin of the cup, are closely set with very many simple papillæ, which are short, obtuse, and dilated at their extremities. A calyciform papilla, perfectly freed from epithelium, and with all the secondary papillæ visible, forms a very beautiful object. (See Plate LXVI. *fig.* 1.)

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* The form and structure of the filiform papillæ, as above detailed, was first described by me in the Lancet of 3rd March, 1849.

The *foramen cæcum* usually contains one and sometimes two large papillæ, similarly clothed with secondary papillæ, and according as it includes one or two papillæ, it is to be regarded as a single or double modified calyciform papilla.

In front of the calyciform papillæ, in some tongues, a number of large and irregular papillæ exist, invested with secondary papillæ similar to those of the calyciform papillæ, but not, like the latter, seated in cups.

On the edges and under surface of the tongue numerous mucous follicles are observed: it is sometimes, however, difficult to distinguish between these and simple papillæ, in consequence of the latter being frequently perforated in the centre, and thus combining the characters of both follicles and papillæ. (See Plate LXV. *figs.* 1, 2, 3.)

The epithelial investment of the tongue adheres very closely to the papillæ, and generally requires one or two weeks' maceration for its complete removal; even then, in but few instances in the human subject, can it be removed in entire pieces, it in most cases crumbling away into its constituent cells.

It adapts itself accurately to the papillary structure of the tongue, and is of sufficient thickness to conceal effectually the simple papillæ, whether these exist by themselves or constitute by their aggregation the compound papillæ. For the satisfactory study of the papillæ, therefore, it is absolutely necessary that the epithelium should be entirely removed.

The epithelium of the tongue presents all the characters of the epidermis of the skin, consisting, like it, of numerous layers of large and nucleated cells, those forming the outer layers being flattened and membranous, while the deeper-seated cells are rounded and granular. (See Plate LXV. *fig.* 6.)

The thickness of the epithelium of the tongue in the human subject varies very considerably in different cases, and would appear to be much affected by disease; it in some cases even being entirely absent.

It is thickest over the simple papillæ, which are usually entirely concealed by it; over the fungiform and calyciform papillæ it is very thin and delicate, while over the filiform papillæ it is prolonged into long filiform processes, which correspond in number and arrangement with the secondary papillæ themselves. (See Plate LIV. *fig.* 1, 2.)

These filiform appendages vary much in length, being very short upon the sides and near the tip of the tongue, but three or four times as long near its centre (see Plate LIV. *fig.* 1, 2.); at the very tip they are often entirely wanting, the papillæ in this situation presenting the appearance of large open follicles with slightly spinous rims. (See Plate LV. *fig.* 4.)

Each filiform process is constituted of flattened epithelial scales, which lie in the direction of their length, and frequently contains a canal in its centre.

Tubular nerve filaments, terminating in loops, have been discovered in the fungiform and filiform papillæ, but not hitherto in either the simple or calyciform papillæ, although nerve filaments, in some form or other, doubtless exist in these also.

The internal minute structure of the three principal forms of compound papillæ requires a careful and searching examination, with a view to the determination of their respective functions. From a consideration of their outward configuration, they would all appear to be well adapted to receive gustatory impressions. The fungiform papillæ seem to be so by their prominence and the delicacy of the epithelium by which they are invested, the calyciform papillæ also by the tenuity of their epithelial covering and by their cupped form, and the filiform papillæ, by reason of the cavity which occupies the centre of each, and the regular disposition of the secondary papillæ around this.

An additional, and to my mind, indeed, an almost conclusive reason in favour of the subserviency of the filiform papillæ to the reception of gustatory impressions, is derived from the consideration that they cover nineteen-twentieths of the mucous membrane of the tongue; and it is but natural to suppose that the principal portion of this is destined to the discharge of the function for which it has so evidently been designed.

The filamentary papillæ have generally been considered to be ill adapted to the reception of gustatory impressions in consequence of the character of the epithelial processes in connection with them; and it has been supposed that they are to be regarded as tactile rather than gustatory organs. This opinion has, however, been entertained in the absence of a full knowledge of the real form and structure of these papillæ, as already shown.

It has occurred to me that these filamentary processes act as absorbents of the nutrient juices, and that collectively they constitute an absorbent surface of considerable power, conveying directly to the papilla those fluids, and keeping them in contact with the papillæ for a time, thus prolonging the duration of the gustatory impression. This idea would appear to gather confirmation from the fact that it is in these filamentary epithelial prolongations that the variable coating known as the fur of the tongue has its seat.

SMELL.

Structure of the Mucous Membrane of the Nose.

The anatomical characters of the mucous membrane of the nose differ in different regions; for a short distance within the anterior nares, the mucous membrane presents many of the characters of the skin, it being divisible into chorion, papillary structure, and epidermis; the papillæ resemble in every respect those of the sense of touch, and the epidermis consists of flattened epithelial scales analogous to those of the same structure in the skin. This, the commencement of the nasal mucous membrane, may be called the *tactile region* of the nose, and it is abundantly furnished with hairs, which guard the entrances of the nares, and the roots of which are in connection with the ordinary sebaceous glands of the hair follicles.

Higher up the mucous membrane of the nose, losing its papillæ and scaly epithelium, becomes thick and soft, and presents more completely the ordinary appearances of a mucous membrane; imbedded in its substance are numerous mucous follicles of large size, having but small apertures, which are best seen thickly studding the surface of the membrane after slight maceration and the removal of the epithelium. Between and around these the blood-vessels are disposed, the veins being particularly large, and forming a very evident plexus, each mesh of which corresponds with a follicle. (See Plate LXIX. *fig.* 2.)

The large size and considerable numbers of the mucous follicles explain the copious secretion which proceeds from this portion of the mucous membrane, when suffering from irritation, while the venous plexuses sufficiently account for the disposition of this part to hemorrhage.

This is by far the largest of the three nasal regions, and may be denominated the *pituatory;* the epithelium which clothes it is of the ciliated kind, and several of the cavities in connection with the meatuses are invested by a similar epithelium, as the fontal and sphenoidal sinuses, the antrum maxillare, and the Eustachian tubes. In the sinuses, however, the mucous membrane, losing its follicles, becomes much reduced in thickness, and presents the characters of a fibrous rather than of a mucous structure.

Still higher up in the nose we come upon the third region, which has been particularly defined and described by the authors of the Physiological Anatomy as follows under the name of the *olfactory region:* —

" The olfactory region is situated at the top of the nose, immediately below the cribriform plate of the ethmoid bone, through which the olfactory nerves reach the membrane; and it extends about one third or one fourth downwards on the septum, and over the superior and part of the middle spongy bones of the ethmoid. Its limits are distinctly marked by a more or less rich sienna-brown tint of the epithelium, and by a remarkable increase in the thickness of this structure, compared with the ciliated region below; so much so, that it forms an opaque soft pulp upon the surface of the membrane, very different from the delicate, very transparent film of the sinuses and lower spongy bones. The epithelium, indeed, here quite alters its character, being no longer ciliated, but composed of an aggregation of superposed nucleated particles, of pretty uniform appearance throughout; except that in many instances a layer of those lying deepest, or almost deepest, is of a darker colour than the rest, from the brown pigment contained in the cells. These epithelial particles, then, are not ciliated; and they form a thick, soft, and pulpy stratum, resting on the basement membrane. The deepest layer often adheres after the others are washed away. On looking on the under surface of this epithelium, when it has been detached, we observe projecting tubular fragments similar to the cuticular lining drawn out of the sweat-ducts of the skin, when the cuticle is removed after maceration. In fact, glands apparently identical with the sweat-glands exist in this region in great numbers. They dip down in the recesses of the submucous tissue, among the ramifications of the olfactory nerves; and their orifices are very easily seen, after the general brown coat of epithelium has been detached, lying more or less in vertical rows; the arrangement is probably determined by the course of those nerves beneath. They become more and more sparing towards the limits of the olfactory region. The epithelium of these glands is bulky, and, like that of the sweat-glands, contains some pigment. As the duct approaches the epithelium of the general surface, its wall becomes thinner and more transparent, and, in its subsequent course upwards, it is difficult to be traced, for it does not appear to be spiral, or its particles to differ from those which they traverse. We have sometimes seen rods of epithelium, apparently hollow, left projecting from the basement membrane, after the brown epithelium has been washed away, and these are perhaps portions of the excretory ducts of these glands."

In the propriety of the discrimination of this region, and in the accuracy of much of the description of it given above, the author fully concurs. He does not, however, hesitate to affirm that no glands at all analogous to sweat-glands exist in it; the membrane of this region is indeed thickly studded with mucous follicles, apparently in no respect dissimilar to those of the pituatory region, except that they are smaller in size, and more delicate in structure.

The chief characteristics of the olfactory region consist, then, in its glandular epithelium, in the presence of pigment cells lying beneath this, in its more delicate structure, in the presence of gelatinous nerve filaments, and in a somewhat different arrangement of the blood-vessels. (See Plate LXIX. *fig.* 1.)

In the sheep this region is rendered almost black by the presence of very many pigment cells which are of the stellate form.

Mr. Quekett pointed out, some years ago, the very curious fact that the blood-vessels of the olfactory region of the human fœtus, and that of mammalia in general, are disposed in loops, the convexity of each of these presenting a decided dilatation. (See Plate LXIX. *fig.* 12.)

Much interest is attached to the existence of these loops, since they appear to indicate the presence of true papillæ in the seat of smell of the mammalian fœtus; if such be the case, however, it is very certain that neither the papillæ nor loops exist in the olfactory region in the adult condition of the nasal organ.

The most rigorous search has failed to detect the presence in the olfactory region of cells, which could be decidedly pronounced to be nervous or ganglionic.

The nerves of the nose are the first pair, branches of the fifth, and motor filaments from the seventh pair. The first pair are, doubtless, the proper nerves of smell, while the fifth gives common sensibility to the nose.

The olfactory lobes are prolongations of the white or fibrous portion of the brain, and consist, like it, of slender tubular nerve filaments, intermixed with the delicate transparent cells, described in a previous division of this work.

" *The olfactory filaments* are from fifteen to twenty-five in number, and passing through the apertures of the cribriform plate, may be seen invested with fibrous sheaths derived from the dura mater, upon the deep or attached surface of the mucous membrane of the olfactory region. They here branch, and sparingly reunite in a plexiform manner, as they descend. They form a considerable part of the entire thickness of the membrane, and differ widely from the ordinary cerebral nerves in structure. They contain no white substance of Schwann, are not divisible into elementary fibrillæ, are nucleated, and finely granular in texture; and are invested with a sheath of homogeneous membrane, much resembling the sarcolemma, or, more strictly, that neurilemma which we figured from the nerves of insects in a former volume. These facts we have repeatedly ascertained, and they appear to be of great importance to the general question of the function of the several ultimate elements of the nervous structure, especially when viewed in connection with what will be said on the anatomy of the retina. We are aware that some anatomists deny the existence of the white substance of Schwann as a natural element of the nerve fibre in any case, pretending that it is formed by artificial modes of preparation. We hold it to be a true structure, but however that may be, these nerves never exhibited it, however prepared. They rather correspond with the gelatinous fibres. Now there is no kind of doubt that they are a direct continuation from the vesicular matter of the olfactory bulb. The arrangement of the capillaries in well-injected specimens is a convincing proof of this, as these vessels gradually become elongated on the nerve assuming a fibrous character as it quits the surface of the bulb; and, further, no tubular fibres can ever be discovered in the pulp often left upon the orifices of the cribriform plate after detachment of the bulb. It must be remembered that a few tubular fibres from the nasal nerve of the fifth here and there accompany the true olfactory filaments; but these only serve to make the difference more evident by contrast." —*Physiological Anatomy.*

VISION.

Structure of the Globe of the Eye.

The structure of the several appendages of the globe of the eye: as the eye-lids, with their lashes, and Meibomian glands, the caruncula lacrymalis, the lachrymal gland, muscles, &c., have already been fully described in previous sections of this work; we have now to enter upon the description of the numerous parts which compose the essential portion of the organ of vision, the globe of the eye; each of these may be examined in much the same order in which they would naturally present themselves to the notice of an ordinary dissector, and which would be somewhat as follows. Schlerotic and cornea; choroid, ciliary processes, and iris; retina; crystalline lens; hyaloid membrane, &c.

Schlerotic.

The schlerotic is composed, to a great extent, of white fibrous tissue, intermixed with a small proportion of a nucleated form of elastic tissue.

These tissues are disposed in a laminated manner, the fibres of one layer crossing those of another more or less at right angles; an arrangement evidently designed to render this the protecting tunic of the eye more firm and unyielding. The inner surface of the schlerotic is rough, and connected with the choroid by the lamina fusca of that membrane, to be described hereafter.

The nutrition of the schlerotic is provided for by small vessels, which ramify on its outer surface, and which are sparingly continued into its substance.

Anteriorly, the schlerotic is strengthened by the tendinous expansion of the four recti muscles, known as the tunica albuginea, or white of the eye.

Cornea.

The cornea, although in a state of health as clear as crystal, yet possesses a complicated and beautiful organisation, plainly demonstrable with the aid of the microscope.

Notwithstanding also the definite line of demarcation by which the limits of the cornea and schlerotic are marked out, these two parts are yet inseparably united to each other; this indissoluble union depending upon the circumstance of the existence of a structural connection between them, the nature of which will shortly be rendered evident.

The cornea is clearly divisible into four, and, according to some observers, even five laminæ; these are, reckoning from before backwards, conjunctival epithelium, cornea proper, posterior elastic lamina, and the epithelium of the aqueous humour; the fifth layer has been described in the "Physiological Anatomy" under the title of the "anterior elastic lamina." These several layers will be separately noticed, and in the order mentioned. (See Plate LXVII. *fig.* 1.)

The *conjunctival epithelium* forms a distinct membrane of appreciable thickness and capable of separation as such shortly after death. It consists of several layers of superimposed cells, which partake of many of the characters of ordinary epidermic scales or cells.

Those cells which constitute the outer or more superficial layers are large, flat, and membranous; whilst those nearest to the cornea proper, and which appear to rest directly upon it, are baton-shaped, and disposed vertically to the surface of the cornea. (See Plate LXVIII. *figs.* 3. 5., and Plate LXVII. *fig.* 1.)

After death this epithelium becomes whitish and opaque, and it then forms the film of the eye.

The second lamina, according to the observations of the author, is the *cornea proper;* and it is this which constitutes the principal bulk of that structure.

Externally, the cornea proper is firm and dense in texture, but becomes more lax and soft gradually as we approach the interior; it is this external and firmer portion which exhibits the lamellar arrangement so generally described, the fibres following a less regular course internally, and being separated by wider intervals.

The tissue of the cornea has been recently described as a peculiar modification of the white fibrous element of the schlerotic. It would appear, however, that the fibrous tissue of which it is constituted is of a kind totally distinct from that which enters so largely into the composition of the cornea proper; a conclusion derived from its examination, for which we might be prepared, simply by the consideration of the very opposite physical characters of the two parts, the schlerotic and cornea, the former being white and opaque, and the latter clear and diaphanous.

If we tear up with needles a small portion of the schlerotic, and examine it with the microscope, we then see that it is made up, for the most part, of bundles of wavy and distinct fibres, presenting scarcely a nucleus, and reflecting a yellowish hue; if now we carry our examination still further, and apply acetic acid to these bundles, they swell up, the fibres becoming indistinct, and finally converted into a jelly-like substance.

On the other hand, if we submit a portion of the cornea to the same examination, and the same treatment by acetic acid, we shall encounter different appearances and results. In the first place, we shall not perceive distinct and separate bundles of fibrous tissue free from nuclei, but we shall merely notice an indistinct fibrous character in the mass, with here and there elongated nuclei imperfectly seen; on the application of acetic acid, however, the fibres become much more evident, and multitudes of nuclei are brought into view. Thus, then, it is evident that the tissue of the cornea is something more than a modification of the white fibrous element of the schlerotic. The nucleated fibres just described are often, in the neighbourhood of the nuclei themselves, expanded and membraneous; and it is remarkable that they do not lie in direct apposition with each other, but interlace in such a manner as to describe elongated spaces, several of which are extended in the same line. These spaces are oval in the cornea, and round in that portion of the schlerotic where the two structures are in connection with each other.* (See Plate LXVII. *fig.* 3.)

This arrangement was first pointed out by the authors of the "Physiological Anatomy," and is thus described by them. "On the cornea proper or lamellated cornea, the thickness and strength of the cornea mainly depend. It is a peculiar modification of the white fibrous tissue, continuous with that of the schlerotic. At their line of junction, the fibres, which in the schlerotic have been densely interlaced in various directions, and mingled with elastic fibrous tissue, flatten out into a membraneous form, so as to follow in the main the curvatures of the surfaces of the cornea, and to constitute a series of more than sixty lamellæ, intimately united to one another by very numerous processes of similar structure, passing from one to the other, and making it impossible to trace any one lamella over even a small portion of the cornea. The resulting areolæ, which in the schlerotic are irregular, and on all sides open, are converted in the cornea into tubular spaces, which have a very singular arrangement, hitherto undescribed. They lie in superposed planes, the continuous ones of the same plane being, for the most part, parallel, but crossing those of the neighbouring planes at an angle, and seldom communicating with them. The arrangement and size of these tubes can be shown by driving mercury, or coloured size, or air into a small puncture made in the cornea. They may also be shown under a high power by moistening a thin section of a dried cornea, and opening it out by needles." In addition to the above it may be remarked, that the spaces may be seen without injection, or any other preparation even in perfectly fresh eyes.

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* A subsequent examination of the cornea renders it necessary that the views above expressed of its structure should be modified to some extent. I find that a considerable amount of a tissue, very closely resembling the white fibrous tissue of the schlerotic, does enter into the construction of the cornea; in sections, however, whether treated or not with acetic acid, this tissue is scarcely to be traced, the nuclear form of fibrous tissue already described, and which is so very abundant, being alone visible, and appearing to constitute the entire of its substance. If, however, a small piece of the inner and softer part of the cornea be torn up with needles, and then examined, bundles of fibrous tissue, very analogous to those of the white fibrous form, will be plainly seen; these are of considerable diameter, reflect a greenish shade, and are, in many parts, transversely striated, each filament bearing a resemblance to a minute Conferva; they are rendered nearly, though not quite, invisible by the action of vinegar. Considered altogether, the cornea resembles very closely, in structure, a tendon, which also contains a very large quantity of a similar nuclear fibrous tissue.

In vertical sections of the cornea, after the application of acetic acid, the nucleated fibres in its outer and denser portion are seen to follow the curved form of the cornea itself, while in its inner and softer part they are variously disposed; horizontal sections of the cornea, even taken from the surface, exhibit a curved and interlaced arrangement of the fibres; fibres also nucleated pass from the surface of the cornea deeply into its substance: the use of these is doubtless to assist in preserving its convexity. (See Plate LXVII. *fig.* 1.)

The *posterior elastic lamina* is the third layer of the cornea: it is a perfectly transparent membrane of appreciable thickness, so that it may be readily recognised with the unaided sight, and is but slightly attached to the cornea proper.

It is usually described as structureless, and in most cases it certainly is so, but in the human eye it frequently exhibits peculiar markings, portrayed in Plate LXVII. *figs.* 11, 12. These, however, would appear to proceed from definite inequalities of the surface rather than from any distinct fibrous or cellular tissue; nevertheless, the appearances observed are remarkable and worthy of record.

This lamina preserves its transparency even in boiling water and acetic acid; and a further peculiarity is, that although it may be torn in any direction, it is so hard that it can be bitten through only with difficulty. It extends to the margin of the cornea only, where it comes into connection with certain elastic fibres to be described hereafter.

The *epithelium of the aqueous humour* is the fourth layer of the cornea: this is of such delicacy and tenuity as to be readily overlooked; it consists of angular cells which form a tesselated epithelium, and rests upon the posterior surface of the elastic lamina above described. (See Plate LXVIII. *fig.* 11.) This epithelium is doubtless concerned in the secretion of the aqueous humour, but it does not appear to extend beyond the limits of the elastic lamina.

The fifth layer, to which reference has already been made, is the anterior elastic lamina, which is described in the third part of "Physiological Anatomy" as follows: — "This is a transparent homogeneous lamina co-extensive with the front of the cornea, and forming the anterior boundary of the cornea proper. It is a peculiar tissue, the office of which seems to be that of maintaining the exact curvature of the front of the cornea; for there pass from all parts of its posterior surface, and in particular from its edge into the substance of the cornea proper, and schlerotic, a multitude of filamentous cords, which take hold, in a very beautiful artificial manner, of the fibres and membranes of those parts, and serve to brace them and hold them in their right configuration. These cords, like the elastic lamina of which they are productions, appear to be allied to the yellow element of the areolar tissue. They are unaffected by the acids. The anterior elastic lamina sustains the conjunctival epithelium which covers the cornea, and is very probably a representative of the basement membrane of the mucous system, as it occupies the corresponding position in regard to the epithelium."

The writer has made diligent and repeated search for this lamina, or for any structure resembling it, without success however; and he has no hesitation in asserting his disbelief in the existence of any membrane in the slightest degree analogous to the posterior elastic lamina in the situation indicated: he is not prepared, however, to deny the presence of an exceedingly thin layer of structureless basement membrane, although of this even he has not yet discovered any evidence, but conceives it possible that it may exist. Its detection has been attempted in several ways;

namely, by vertical and horizontal sections, and by the use of re-agents, but to no purpose.

In a representation of a vertical section of the human cornea given in the "Physiological Anatomy," this anterior elastic lamina is represented as being three or four times the thickness of the posterior lamina, so that there ought to be but little difficulty in its detection were it present on the face of the human cornea.

The "elastic cords" mentioned would appear to be nothing more than the nucleated fibres already described as passing in a curved manner from the surface of the cornea, and extending deeply into its substance. (See Plate LXVII. *fig.* 1.)

Choroid.

The next membrane met with in the usual order of dissection, is the choroid: this adheres intimately to the schlerotic in the neighbourhood of the larger trunks of the venæ vorticosæ; but more slightly in the intervals between, being united to it only by the lamina fusca.

The choroid forms a thick membrane, externally of a chocolate colour, flocculent and rough, but internally of a bluish-black colour and smooth; its substance is made up of numerous blood-vessels, and of an immense quantity of pigment in connection with a peculiar form of fibrous tissue.

The tissue of which the choroid is composed, has been hitherto stated to resemble the fibrous tissue of the schlerotic: this is not the case, however, as indeed might have been inferred from the ease with which it tears, especially in the course of the vessels, and the absence of bundles of fibres on the torn and divided margins: the fibrous element of the choroid is of a peculiar kind, to be more fully described hereafter, and unlike any other form existing in the human body.

The *blood-vessels* of the choroid are usually described as forming two layers, and this they may be fairly considered as doing, although the two lamellæ are not perfectly distinct from each other, being connected by numerous blood-vessels which pass between them.

These laminæ may be designated in general terms separately as *arterial* and *venous:* the inner or arterial lamina, known as the *tunica Ruyschiana,* consists of a dense and beautiful plexus of vessels, which are so closely applied to each other as scarcely to leave any intervening spaces or meshes. (See Plate LXVII. *fig.* 4.) The main arteries which supply this tunic, and the veins which carry off its blood, leave it by numerous points on its outer surface only; the veins are particularly large and numerous, and disposed in beautiful curves, whence they are called *venæ vorticosæ.* (See Plate LXVIII. *fig.* 2.) Before leaving the choroid they converge to form four or five principal trunks which enter the schlerotic; the arteries, fewer in number and much smaller in size, run between the veins.

An immense number of granular nuclei are visible in the walls of the venæ vorticosæ.

Stellate choroidal epithelium. — Such is the distribution of the blood-vessels of the choroid: the next most important element in its constitution are the pigment cells; these exist in vast quantities and make up much of its substance; they are of various forms and sizes; but being furnished with two, three, or more arms or radii, they may be aptly termed *stellate.* The nucleus in each cell is large and particularly clear, appearing almost like a hole in its centre: this is owing to the absence of the colouring matter contained in each cell in that situation.

The existence of the stellate form of pigment cells in the human subject appears to have been generally overlooked: it was described and figured in Parts 7 and 8 of the Microscopic Anatomy published in February and March, 1847, and its arrangement in rows was at the same time pointed out; its position in the choroid, as well as its structure, have since been examined with more care, and with the following results.

This pigment is situated beneath the tunica Ruyschiana, and in the intervals between the venæ vorticosæ, which it accurately fills up, some of the arms of the cells, as well as occasionally a few of the scattered cells, intrenching upon the veins: thus, then, its disposition is a counterpart of that of the venæ vorticosæ, the dense rows of cells exhibit the same curves, the same mode of branching, and viewed altogether with a low object-glass in the eyes of some animals, as the sheep, nothing can exceed the beauty and elegance of the object thus presented to our examination. (See Plate LXVIII. *fig.* 1.)

With regard to structure, it is remarkable that each radius or arm of the cells is prolonged into a colourless fibre, in the course of which several other cells may be included. (See Plate LXVIII. *fig.* 13.)

This structure is best seen in the *lamina fusca,* the fibres of which are all of this nature, and are exceedingly diaphanous, often membranous, much disposed to curl up, and unaffected by distilled vinegar, beyond undergoing a degree of contraction. All the fibres met with in the choroid, except those entering into the constitution of the blood-vessels, are of this peculiar nature.

The inner surface of the choroid is so smooth as to convey the impression of the existence of a distinct membrane: of this, however, no satisfactory evidence has yet been obtained, although portions of membrane apparently devoid of structure have been seen on the margins of torn portions of the choroid. If a membrane does really exist in this situation, it is possible that it is nothing more than the vessels of the tunica Ruyschiana united into a membrane by the fibres above described.

Hexagonal choroidal epithelium. — On the inner surface of the choroid a layer of cells of a regularly pentagonal or hexagonal form, filled with pigmentary granules, exists: these cells are so coherent that they form a distinct layer much more evident in the eyes of some animals, as the sheep and pig, than in those of man. (See Plate LXVIII. *fig.* 12.)

This layer extends over that peculiar structure common to the eyes of many quadrupeds and fishes, the *tapetum lucidum;* but in that situation its component cells are of smaller size, and almost entirely deprived of colouring matter.

In albinoes the colouring matter is deficient, not only in the cells of tapetum lucidum, but also in those of the hexagonal and stellate choroidal epithelium.

The *tapetum lucidum* is a layer of fibrous tissue implanted upon the choroid, possessing the remarkable property of refracting unequally the rays of light which fall upon it, and hence its brilliancy and metallic lustre: acetic acid destroys to some extent this peculiarity; the stellate pigment is continued behind the tapetum lucidum, which singular and beautiful structure acts as a concave reflector, its use being to economise light and to cause the rays to traverse the retina a second time, by which means animals possessing it are enabled to discern objects in a light which would be insufficient for the purpose in the absence of such a provision.

The description of the choroid now given includes that portion of it only which corresponds to the retina, and which ceases at a line known as the ora serrata; about the eighth of an inch behind the margin of the cornea, in front of this line as far as the iris, the choroid is known as the ciliary body; this is covered behind by a layer of non-striated muscular fibre, the ciliary muscle (see Plate LXVIII. *fig.* 4.), and from it the ciliary processes descend.

Ciliary processes. — These processes, usually reckoned at about sixty in number, are received into corresponding folds or plaitings of the hyaloid membrane, called the *secondary ciliary processes,* and which taken altogether form a circle around the crystalline lens named after their discoverer the *Zone* of *Zinn:* they are each composed of numerous blood-vessels (see Plate LXVII. *fig.* 4.), fibrous tissue, irregular pigment cells; and " on their inner surface is a tough colourless lamina, composed of ill-defined nucleated cells continuous with the border of the retina, but clearly not composed of nervous matter, by means of which they are immediately connected with the hyaloid membrane."

The *iris* may be regarded as an extension of the choroid, although it does not exhibit all the anatomical characters of that membrane; it is made up of a considerable quantity of pigment cells, of blood-vessels, and of fibres of unstriped muscle. (See Plate LXVIII. *fig.* 9.)

The pigment cells constituting the posterior layer of the iris, and called *uvea,* are irregular in size and form, as are those also situated amongst the fibres of the iris; upon the varieties in the colouring matter contained in these last, many of the differences observable in the iris of different persons and animals depend. (See Plate LXVIII. *fig.* 14.)

The muscular fibres of the iris in the human subject are of the unstriped kind and follow two courses, a radiating and a circular; in birds, however, the radiating fibres consist of striped muscular fibres, and they surround immediately the pupil; the one set of fibres dilates the pupil, the other contracts it.

The blood-vessels of the iris are very numerous, and are derived chiefly from the two long ciliary arteries, which on approaching the iris bifurcate and form an arch around it, whence pass inwards a number of branches which form loops near the pupillary margin.

"On the anterior surface, near the pupil, a vascular circle marks the line from which in the fœtus the *membrana pupillaris* stretched across in front of the pupil. This membrane at that early period divides the posterior from the anterior chamber, and receives from several parts of the circular vessel last mentioned small branches, which approach the centre and then return in arches after inosculating sparingly across the central point." The membrana pupillaris is almost absorbed at birth.

The iris, according to the authors of the Physiological Anatomy, "is attached all round at the junction of the schlerotic and the cornea, so near indeed to the latter that its anterior surface becomes continuous in the following manner with the posterior elastic lamina. This lamina, near its border, begins to send off from its anterior surface, or that towards the laminated cornea, a network of elastic fibres, which stretch towards the border, becoming thicker as they advance, until at length the entire thickness of the lamina is expended by being converted into them. These fibres then bend backwards from the whole circumference of the cornea to the circumference of the front of the iris, and are there implanted, passing in this course across the line of the anterior chamber and through the aqueous humour. They are seen more easily in some animals than in others, forming a regular series of pillars around the anterior chamber."

It would appear, however, that these fibres, which may be readily detected in the human eye, should rather be described as proceeding from the schlerotic, and passing, some on the anterior surface of the elastic lamina, and others on the front of the iris, thus assisting in uniting these parts to that tunic; it is very doubtful whether they have any structural connection with the posterior elastic lamina. (See Plate LXVIII. *fig.* 8.)

The ciliary nerves pierce the ciliary muscle on their way to the iris.

Retina.

We come in the next place to the description of the most interesting and important of the many structures which enter into the composition of the globe of the eye, namely, the retina. This membrane may be regarded as the expansion of the optic nerve, to which certain other structures are superadded, and, like most of the other membranes of the eye, is divisible into distinct lamellæ; these, reckoning from without inwards, are, tunica Jacobi, or "stratum bacillosum," the granular or nuclear layer, the ganglionary layer, the vesicular layer, the fibrous expansion of the optic nerve, and, lastly, the vascular expansion of the arteria centralis retinæ.

The *tunica Jacobi* is composed of a single stratum of cells of very remarkable form. They are minute in size, several times longer than broad, having their long axes disposed vertically to the general surface of the retina, and they each consist of a body or head of a more or less globular or oval shape, and of a prolongation or tail, four or five times longer than the head, and not more than a third of its diameter. By their coherence these cells form a distinct membrane, the heads of the cells all being directed one way, namely, towards the surface of the choroidal epithelium, and the tails disposed in an opposite direction. Although these cells adhere together with sufficient firmness to constitute a distinct membrane, it would appear that they possess a certain power of movement upon each other, for it is only on such a supposition that we can explain satisfactorily the fibrous appearance which this membrane frequently presents when viewed in extenso. (See Plate LXVII. *fig.* 9.)

The tunica Jacobi, although certainly not a nervous structure, is yet properly enumerated as one of the layers of the retina, since it never adheres on the removal of the latter to the choroidal epithelium, but always to the second or granular layer of the retina itself: on account of its extreme frailty and delicacy, this membrane is only to be satisfactorily studied in extremely fresh eyes. A few hours after death the cells separate from each other, and the heads of the cells become disjointed from the tails, so that in the course of a short time not a vestige of the membrane remains.

Each cell of the stratum bacillosum bears not an inexact resemblance to a human spermatozoon, than which it is however less considerable in size.

The *granular layer* consists not of granules merely, as the name implies, but of numerous nuclei imbedded in granular matter, and each of which contains several dark spots which reflect the light strongly. This layer is of considerable thickness, and is described in the "Physiological Anatomy" as being divided into two, of which the inner is much the narrower, by a *pale stratum* which can only be seen by very careful manipulation. The nuclei of which it is composed bear much resemblance to those which occur in the convolutions of the brain, and are most probably of the same nature. (See Plate LXVII. *figs.* 5, 6.)

The next is the *ganglionary layer:* this appears to have been hitherto altogether overlooked; its discovery supplies a desideratum in the anatomy of the eye, and clearly shows the really nervous character of the granular and vesicular strata of the retina, which many persons have been much disposed to doubt.

This layer is exceedingly thin and delicate, hardly indeed to be considered as a distinct stratum, but yet consisting of numerous caudate ganglionary globules, in every respect similar in point of structure to those which have been described as occurring in so many of the ganglia of the human brain.

These caudate cells differ considerably in size, but yet are all referable to one of two standards, the larger very much exceeding the smaller in dimensions. (See Plate LXVII. *fig.* 8.)

It is in the human retina only that these cells have as yet been detected.

The fourth or *vesicular layer* lies immediately on the outer surface of the fibrous layer, the cells composing it are several times larger than the nuclei of the granular layer; a few of the most external of them are granular and nucleated, but the majority, and these the larger cells, are clear and transparent as water, perfectly globular, and without appreciable nuclei. The cells of the vesicular layer resemble very closely the delicate cells which have been described in a previous part of this work, as found in the fibrous portions of the human brain. (See Plate LXVII. *fig.* 7.)

The *fibrous gray layer* is best seen and most strongly marked in the retina near to the optic nerve. If a portion of this membrane be cut off and spread out upon glass, it will be seen to present, viewed with the inch or half-inch object-glass, a number of parallel or rather radiating flattened bands, two of which occasionally divide or bifurcate.

If, in the next place, these bands or bundles, having been separated somewhat from each other by means of needles, and as much of the granular layer which so obscures them washed away with a camel's hair brush as possible, be then examined, they will each be observed to present a fibrous appearance, and on a prolonged and careful examination it will become apparent that they are made up, first, of a small quantity of nucleated fibrous tissue, and, secondly, and principally, of gray gelatinous, nerve fibres. (See Plate LXVIII. *fig.* 6.)

That these gelatinous fibres constitute the principal portion of the fibrous layer of the retina, and that no tubular nerve fibres exist in the retina itself, are points upon which not the smallest doubt can be entertained.

Of the reality of the transformation of the tubular into the gelatinous nerve filament, that is, the conversion of a tubular, unbranched, and unnucleated structure into a branched, and nuclear tissue, great misgivings might be well entertained; an attentive study of the structure of the fibrous gray layer of the retina renders it very difficult, however, to deny the reality of such a structural transition.

The *vascular lamina* is the last of the layers of the retina: it would appear to be entirely distributed upon the inner surface of the fibrous layer; for if we take a perfectly fresh eye and spread the retina out with its inner surface upwards, we can readily see the larger blood-vessels filled with blood corpuscles, and having the fibrous layer situated immediately behind them. (See Plate LXVII. *fig.* 2.)

The *optic nerves* consist of several bundles of nerve tubules: these are very slender and brittle, and interspersed with delicate globular cells; in these last two particulars these nerves correspond with the white fibrous portions of the brain.

The transparent media of the eye are the vitreous body and the crystalline lens with its capsule.

Vitreous Body.

The *vitreous humour* is enclosed in a perfectly structureless and exceedingly delicate membrane called the *hyaloid membrane:* this does not enclose the whole of the vitreous humour, but is deficient behind the crystalline lens, it being inserted into the side of the capsule of that body.

From all points of the inner surface of this membrane fibres proceed; these interlace with each other in such a manner as to form a cellated structure.

The size and structure of these cells may be readily seen with an inch or half-inch object-glass; and the best view of them is obtained in the neighbourhood of the zona ciliaris. (Plate LXVIII. *fig.* 7.)

Granular nuclei of large size are seen on the walls of the cellated spaces; these are most probably concerned in the secretion of the vitreous humour. That these several cellated spaces communicate with each other, seems proved by the fact that if the hyaloid membrane be ruptured, the whole of the vitreous humour will gradually escape through the aperture.

A layer of cells of large size and of such extreme transparency as to be discovered only with great difficulty, are described in the "Physiological Anatomy" as situated on the hyaloid membrane between it and the retina: these have not fallen under the observation of the writer.

The *vitreous body*, then, consists of the hyaloid membrane, cellated fibrous structure, the zone of Zinn, and of the vitreous humour. Through the centre of this body a branch of the central artery of the retina passes in early life, destined for the posterior part of the capsule of the lens.

Crystalline Lens.

The *crystalline lens* is composed of capsule and body.

The *capsule* is formed of a thin lamella of elastic tissue, much thicker before than behind, but in all essential particulars similar to the posterior elastic lamina of the cornea. The manner in which it is attached to the hyaloid membrane has been already pointed out; it now remains to observe that the cellated fibres of the vitreous body are also inserted into its posterior part. It is perfectly closed on all sides, so that in the adult condition of the eye neither vessels nor nerves pass through it to the lens.

The *body* of the lens, transparent and jelly-like as it appears to the unaided sight, is yet full of elaborate and elegant structure. It consists of very many layers or concentric lamellæ of flattened fibres, which radiate from the centre and are disposed in a parallel manner with reference to each other; the fibres, however, have a more complicated arrangement than this, as will be evident from what follows.

In the Mammalia in general there are visible on the front surface of the lens, when this has slightly lost its transparency, three radiating grooves or lines, the points of which terminate at about one-third from the border of the lens. On the opposite surface of the lens there exist three similar lines, occupying an intermediate position. From these lines the fibres pass from the one surface on to the other; thus a fibre which starts from the point of one of the lines in front, passes over the border of the lens, advances midway between two lines on the opposite surface, and is inserted in the angle of division of those lines; another fibre starting from between two lines in front, is lost on the extremity of a line situated posteriorly: the rest of the fibres occupy positions intermediate to these. If, in the next place, we bear in mind the fact that these lines, seen on the surface of the lens, are but the edges of planes which pass through the centre of the lens, affording points of divergence and concourse for all the fibres, deep as well as superficial, we shall readily comprehend what, without this explanation, would have appeared an intricate arrangement; and we shall perceive why it is that the lens, when hardened in spirit or boiled in water, is prone to separate into concentric lamellæ and into three triangular segments. From the above arrangement it results, also, that all the fibres, whether superficial or deep-seated, decrease in width as they approach the centre of the lens on either surface, and also that the superficial are longer and larger than the deeper seated. (See Plate LXVII. *fig.* 13.)

The edges of the fibres are most beautifully toothed and dovetailed together, as was first pointed out by Sir David Brewster. This toothing is best seen in the eyes of fishes; it is also clearly manifest, although on a smaller scale, in the fibres of the lens of most mammalia and of man. (See Plate LXVII. *fig.* 10.)

On the surface of the lens beneath the capsule, and occupying the space between these, a delicate epithelium exists, very similar to that on the posterior elastic lamina. (See

Plate LXVIII. *fig.* 10.) After death, this space is occupied by a small quantity of fluid, the liquor Morgagni.

Beneath this epithelium, again, other small oval granular cells are encountered; from these possibly the fibres of the lens take their origin.

The lens is of less density externally than internally; this is also one of the results of the peculiar form and arrangement of the fibres.

In the adult eye the lens is entirely destitute of blood-vessels, although during its development in the fœtus it is copiously supplied with them.

THE ORGAN OF HEARING.

ELABORATE as is the organisation of the ear, it yet presents less to interest the microscopical anatomist than many other of the organs which enter into the composition of the human fabric. The ear is divisible into three portions — the limits of each of which are well defined — an external, a middle, and an internal: the external portion is an apparatus for the collection of sound; the middle is designed for its conveyance to the internal or true and essential division of the organ of hearing.

The External Ear.

The external ear consists of the expanded part or auricle, and the external meatus.

The auricle. The auricle presents several eminences and depressions, many of which have received distinct names; it is made up of integument, cartilages, and fat; the integument is thin and delicate, and is furnished with but few sebaceous glands; the cartilages are of the fibrous kind, and are three in number, — the larger forming the pinna, being separated from that of the tragus and antitragus, by grooves filled up with fibrous tissue; lastly, the fat is situated chiefly in the lobe of the ear. Ligamentous bands bind the auricle to the bone, while its movements are effected, in part, by muscular fibres which pass between the prominent parts of its constituent cartilages, but mainly, by three small muscles of the striped variety, and each of which has received a distinct name.

The Auditory Canal.—The auditory canal consists of two parts,—a cartilaginous and an osseous; the first is formed by the prolongation inwards of the cartilages of the auricle; these form a tube, deficient at the upper and back part, where the place of cartilage is supplied by a fibrous membrane; this tube is inserted into the auditory process of the temporal bone: the osseous part of this canal is formed by the auditory process already alluded to; this process in the adult is nearly three-quarters of an inch long, and to its outer margin the tympanum is attached, the bone being grooved for its reception: in the fœtus, the auditory process is a detached ring of bone, into which, however, the tympanum is inserted.

The orifice of the meatus is defended by hairs, the bases of which are in connection with sebaceous glands; still further inwards, but limited to the cartilaginous part of the passage, the ceruminous glands are encountered: these have already been described.

According to some observers, muscular fibres exist in the external meatus, which becomes shortened by their contraction.

The Middle Ear.

The middle ear consists of the tympanum, tympanic cavity, and the ossicles with their muscles.

The *tympanum*, or tympanic membrane, is divisible into three laminæ—an external or cuticular, a middle or fibrous, and an internal or ciliated; the external is a continuation of the cuticle which lines the external meatus, and may be separated as a distinct membrane; the fibrous tissue, of which the internal lamina of the tympanum is composed, is strong and dense, and is arranged in a radiated manner; into this the handle of the malleus is inserted: the blood vessels which supply the tympanum pass along the handle of the above-named bone, and follow the same radiated course as the fibres themselves; the inner and third lamina is composed of cells of ciliated epithelium, similar to those lining the tympanic cavity.

The *tympanic cavity* is lined by a fibrous membrane, divisible into two layers; the fibres entering into the composition of one of these follow a longitudinal course, while those of the other layer are circularly disposed; these fibres are, for the most part, nucleated, and would appear to be of the elastic kind: in the longitudinal layer, the fibres are disposed in bundles, and are possibly contractile: on the surface of this membrane and lining immediately the tympanic cavity, is a layer of ciliated epithelium, continuous on the one hand with that of the tympanic membrane; and on the other, with that clothing the interior surface of the Eustachian tube.

Posteriorly, the tympanic cavity exhibits the openings of the mastoid cells; anteriorly, the orifice of the Eustachian tube may be noticed, while the internal wall of the tympanum presents two orifices which communicate with the internal ear: these are the fenestra ovalis, leading into the vestibule; and the fenestra rotunda, opening into the cochlea.

The whole length of the tympanic cavity is traversed by a chain of three bones, united to each other by muscles of the striped kind; one extremity of this chain is attached, as already noticed, to the tympanum, while the other, formed by the base of the stapes, is in connection with the fenestra ovalis.

In the tympanic cavity of the ear of the sheep, cells, containing pigment, may very generally be observed; amongst these, I have noticed the occurrence of numerous delicate transparent cells, similar to those of the white substance of the brain and spinal marrow.

The Internal Ear or Labyrinth.

The internal ear, which is the essential portion of the organ of hearing, consists of three parts: — the vestibule, the semicircular canals, and the cochlea: these are cavities imbedded in the petrous bone, communicating with the tympanic cavity on the one side, by the fenestræ ovalis and rotunda; and on the other, with the internal auditory canal. The dense bone immediately surrounding these cavities is termed the *osseous labyrinth,* in contradistinction to the *membranous labyrinth* contained within them. The description of the form, &c. of the osseous labyrinth belongs rather to descriptive than to general or microscopic anatomy, and therefore will not here be entered upon.

The osseous labyrinth contains a fluid which has been called the *perilymph,* from its surrounding, though in the vestibule and semicircular canals only, a hollow membranous apparatus — the membranous labyrinth, which itself contains a fluid, the *endolymph.*

The following account of the structure of the spiral lamina; of the cochlea; the cochlear muscle; the cochlear nerves; the membranous labyrinth; the vestibular and auditory nerves, is copied from the "Physiological Anatomy."

Of the Structure of the Spiral Lamina of the Cochlea.— "We shall term the two surfaces of this lamina, tympanic and vestibular, as they regard, respectively, the tympanic or vestibular scala. The *osseous* portion of the spiral lamina extends more than half way from the modiolus towards the outer wall, and is perforated, as already described, by a series of plexiform canals, for the transmission of the cochlear nerves; these canals, taken as a whole, lie close to the lower or tympanic surface, and open at or near the margin of this zone. The *vestibular* surface of the osseous zone presents, in about the outer fifth of its extent, a remarkable covering, more resembling the texture of cartilage than anything else, but having a peculiar arrangement, quite unlike any other with which we are acquainted. Being uncertain respecting the office of this structure, we shall term it the *denticulate* *lamina* (Plate LXIX. *fig.* 3.), from a beautiful series of teeth, forming its outer margin, which project far into the vestibular scala, and, in the first coil, terminate almost on a level with the margin of the osseous zone, but more within this margin towards the apex of the cochlea. They thus constitute a kind of second margin to the osseous zone, on the vestibular side of the true margin, and having a groove beneath them, which runs along the whole lamina spiralis, in the vestibular scala, immediately above the true margin of the osseous zone. The intervals between the teeth, are to be seen on their upper surface, on their free edge, and also within this groove, so that the teeth are wedge-shaped, and their upper and under surfaces, traced from the free edge, recede. The free projecting part, or teeth of the denticulate lamina, form less than a fourth of its entire breadth, and in the remainder of its extent, it appears to rest on the osseous zone; seen from above, after the osseous zone has been rendered more transparent by weak hydrochloric acid, rows of clear lines may be traced from the teeth at the convex edge, towards the opposite or concave edge of the lamina. These lines appear to be a structure resembling that of the teeth themselves, and they are separated from one another by rows of clear, highly refracting granules, which render the intervals very distinct. These intervals are more or less sinuous and irregularly branched.

"The denticulate lamina, thus placed on the vestibular surface of the osseous zone, is above, and at some distance from the plexus of the cochlear nerves, which lies near its tympanic surface. The vestibular surface of the osseous zone, including the denticulate lamina, is convex, rising from the free series of teeth towards the modiolus.

"In the groove already mentioned, there is a series of elongated bodies, not unlike columnar epithelium, in which the nuclei are very faint.

"These bodies are thick and cubical at one end, and taper much towards the other. They are united in a row, and it is possible they may have some analogy to the club-shaped bodies of Jacob's membrane. We can assign them no use.

"Continuous with the thin margin of the osseous zone is the *membranous zone.* (Plate LXIX. *fig.* 4.) This is a transparent glassy lamina, having some resemblance to the elastic laminæ of the cornea, and the capsule of the lens. A narrow belt of it, next the osseous zone, is smooth, and exhibits no internal structure, while, in the rest of its width, it is marked by a number of very minute straight lines, radiating outwards from the side of the modiolus. These lines are very delicate at their commencement, become more strongly marked in the middle, and are, again, fainter ere they cease, which they do at a curved line on the opposite side. Beyond this, the membranous zone is, again, clear and homogeneous, and receives the insertion of the cochlearis muscle. The *inner clear belt* of the membranous zone is little affected by acids: it seems hard and brittle. The middle or *pectinate portion* is more flexible, and tears in the direction of the lines. The *outer clear belt* is swollen, and partially destroyed by the action of acetic acid. Along the inner clear belt, and on its tympanic surface, runs a single, sometimes branched vessel, which would be most correctly called a capacious capillary, as it resembles the capillaries in the texture of its wall, but exceeds them in size. It is the only vessel supplied to the membranous zone, and seems to be thus regularly placed, that it may not mar the perfection of the part as a recipient and propagator of sonorous vibrations.

Of the Cochlearis Muscle. — "At its outer or convex margin, the membranous zone is connected to the outer wall by a semitransparent structure. This gelatinous-looking tissue was observed by Breschet, and is, indeed, very obvious on opening the cochlea; but we are not aware of any one having hinted at what we regard to be its real nature. The outer wall of the cochlea presents a groove, ascending the entire coil, opposite the osseous zone of the lamina spiralis, and formed principally by a rim of bone, which, in section, looks like a spur, projecting from the tympanic margin of the groove, the opposite margin being very slightly or not at all marked. This groove diminishes in size towards the apex of the cochlea. It gives attachment to the structure in question, by means of a firm dense film of tissue, having a fibrous character, and the fibres of which run lengthwise in the groove, and are intimately united to it, especially along the projecting rim. From this *cochlear ligament*, the cochlearis muscle passes to the margin of the membranous zone, filling the groove and projecting into the canal, so as to assist in dividing the tympanic and vestibular scalæ from one another, and thus forming, in fact, the most external or the *muscular zone* of the spiral laminæ. Thus the cochlear muscle is broad at its origin from the groove of bone, and slopes above and below to the thin margin in which it terminates, so that its section is triangular, and it presents three surfaces, one towards the groove of bone, and one to each of the scalæ. The surface towards the vestibular scala is much wider than that towards the tympanic scala, and presents, in a band running parallel to and at a short distance from the margin of the membranous zone, a series of arched vertical pillars with intervening recesses, much resembling the arrangement of the musculi pectinati of the heart. (Plate LXIX. *fig.* 5.) These lead to, and terminate in, the outer clear belt of the membranous zone, which forms a kind of tendon to the muscle. This entire arrangement is almost sufficient of itself to determine the muscular nature of the structure. If its fibres were of the striped variety, no doubt would remain; but its mass, evidently fibrous, is loaded with nuclei, and filled with capillaries, following the direction of the fibres, and in almost all respects it has the closest similarity to the ciliary muscle of the eye.

"The capillaries of the ciliary muscle are derived from vessels meandering over the walls of the scala before entering it, and those from above and below do not anastomose across the line of attachment of the membranous zone; thus indicating that the continuation of this zone enters as a plane of tendon into the interior of the muscle, dividing it into two parts, and receiving the fibres in succession.

"The scalæ of the cochlea are lined with a nucleated membrane, or epithelium, which is very delicate and easily detached, usually more easily seen in the vestibular than in the tympanic scala, and in many animals containing scattered pigment.

Of the Cochlear Nerves.—"These enter from the internal auditory meatus through the spirally-arranged orifices at the base of the modiolus, and turn over in succession into the canals hollowed in the osseous zone of the spiral lamina, close to its tympanic surface. In this distribution the nervous bundles subdivide and reunite again and again, forming a plexus with elongated meshes, the general radiating arrangement of which may be readily seen through the substance of the bone when it has been steeped in diluted hydrochloric acid. (Plate LXIX. *fig.* 6.) Towards the border of the osseous zone, the bundles of the plexus are smaller and more closely set, so as at length almost to form a thin uniform layer of nervous tubules. Beyond the border, and partially on or in the inner transparent belt of the membranous zone, these tubules arrange themselves more or less evidently into small sets, which advance a short distance and then terminate much on the same level. These terminal sets of tubules are cone-shaped, coming to a kind of point ere they cease. The white substance of Schwann exists in them throughout, but is thrown into varicosities and broken with extreme facility, and they are interspersed with nuclei, so that it is very difficult to discover the precise disposition of the individual tubules. They seem to cease one after another, thus causing the set to taper; and at least it appears certain that evidence of loopings such as have been described by some, is wanting. In the cochlea of the bird, however, we have seen at one end a plexiform arrangement of nucleated fibres ending in loops; but this is a peculiar structure.

"The capillaries of the osseous zone are most abundant on the tympanic scala, in connection with the nerves now mentioned, and form loops near the margin, with here and there an inosculation with the large marginal capillary already mentioned.

Of the Membranous Labyrinth.—"This has the same general shape as the bony cavities in which it lies, but is considerably smaller, so that the perilymph intervenes in some quantity, except where the nerves passing to it confine it in close contact with the osseous wall. Its vestibular portion consists of two sacs, viz. a principal one of transversely oval figure and compressed laterally, called the *utriculus,* or common sinus, occupying the upper and back part of the cavity, in contact with the fovea semi-elliptica, and beneath this a smaller and more globular one, the *sacculus,* lying in the fovea hemispherica, near the orifice of the vestibular scala of the cochlea, and probably communicating with the utriculus.

" The *membranous semicircular canals* have the same names, shape, and arrangement as the osseous canals which enclose them, but are only a third of the diameter of the latter. As the osseous canals open into the vestibule, so the membranous ones open at both ends into the utriculus, there being, however, a constricted neck between this sac and the ampullated extremity of each canal. The auditory nerve sends branches to the utriculus, to the sacculus, and to the ampulla of each membranous canal. These nerves enter the vestibule by the minute apertures before described, and tie down, as it were, both the utriculus and sacculus to the osseous wall at those points, the membrane being much thicker and more rigid at those parts. The branches to the ampulla of the superior vertical and the horizontal semicircular canals enter the vestibule with the utricular nerve, and then cross to their destinations, while that to the ampulla of the posterior vertical canal traverses the posterior wall of the cavity and opens directly into the ampulla.

" The wall of the membranous labyrinth is translucent, flexible, and tough. When withdrawn from its bed and examined, it appears to present three coats, an outer, middle, and internal. The outer is loose, easily detached, somewhat flocculent, and contains more or less colouring matter disposed in irregular cells exactly resembling those figured at page 22., from the outer surface of the choroid coat of the eye. We have not found a true epithelium on this surface. The middle is the proper coat, and seems more allied to cartilage than any other tissue; its limits are well marked, it is transparent, and exhibits in parts a longitudinal fibrillation; treated with acetic acid, it presents numerous corpuscles or cell nuclei. Where it is thinnest it has a near resemblance to the hyaloid membrane of the eye. The internal coat is composed of nucleated particles, closely opposed, and but slightly adherent; the nuclei are often saucer-shaped, and when seen edgeways have the uncommon appearance of a crescent. They easily become detached and fall into the endolymph. Minute arteries and veins, derived chiefly from a branch of the basillar accompanying the auditory nerve, enter the vestibule from the internal meatus, and ramify on the exterior of the membranous labyrinth, apparently bathed in the perilymph. A beautiful network of capillaries, forcibly reminding the observer of that belonging to the retina, is spread out on the outer surface and in the substance of the proper coat. These vessels have the simple homogeneous wall interspersed here and there with cell nuclei, that characterises the capillary channels in many other situations. There is an abundant network of capillaries in the interior of the utriculus and sacculus, about the terminal distribution of the nerves, which evinces the activity of the functions of these parts.

"The membranous labyrinth, or its simple representative the auditory sac, contains in all animals either solid or pulverulent calcareous matter in connection with the termination of the vestibular nerves. This has been called by Breschet *otolith* or earstone, when solid, as in the osseous fishes, and *otoconia* or ear-powder, when in the form of minute crystalline grains, as in Mammalia, birds, and reptiles; but the former term may be conveniently employed to designate both varieties. In the Mammalia, including man, it is found accumulated in small masses about the termination of the nerves, both in the utriculus and sacculus, and we have found it also sparingly scattered in the cells lining the ampullæ and semicircular canals. In the vestibular sacs it appears to be entangled in a mesh of very delicate branched fibrous tissue, in connection with the wall, and it is most probably held in place by cells within which, according to Krieger *, its particles are deposited. It has a regular arrangement, and is not free to change its place in the endolymph. Otolithes consist always of carbonate of lime.

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* De Otolithis. Berol, 1840.

Of the Vestibular Nerves.—"In consequence of the thickness of the wall of the membranous labyrinth where the nerves enter, and the presence there of the calcareous and fibrous matter, it is not easy to ascertain with certainty the precise manner in which the nerves terminate. In the utricule and saccule, they appear to spread out from one another as they enter, and then to pass, some to mingle with the calcareous powder, others to radiate for a small extent on the inner surface of the wall of the cavity, where they come into connection with a layer of dark and closely set nucleated cells, and presently loose their white substance. We have seen a fibrous film on the inner surface of these parts which we are disposed to consider as formed, like the inner surface of the retina, by the union of the axis-cylinders of the nerve tubes, but confirmatory observations are required. Those that traverse the calcareous clusters have appeared to us, in the most lucid views we have succeeded in obtaining, to terminate by free, pointed extremities, without losing their white substance. In the frog this has been evident enough.

"The nervous twigs belonging to the semicircular canals do not seem to advance beyond the ampullæ, in which they have a remarkable distribution, entering them, as Steifensand has well shown, by a transverse or forked groove, on their concave side, and which reaches about a third round. Within this, the nerve projects so as to form a sort of transverse bulge within the ampulla. Their precise termination can be best seen in the osseous fishes, and has been described by Wagner to be loop-like. We believe we have seen this mode of termination, though certainly never so plainly as the figure given by this excellent author would indicate; and we may add that we have found free extremities to the nerve tubes, as well as loopings, in the ampullæ of the cod. The difficulty in these cases of ascertaining the exact truth arises from the curves formed by the nerve tubes in proceeding to their destination, and which are liable to be mistaken for terminal loopings.

Of the Auditory Nerves. — "At the bottom of the meatus, the portio mollis divides into two branches, one to the vestibule and semicircular canals, the other to the cochlea.

"The vestibular nerve divides into three branches; — the largest is uppermost, and penetrates the depression which is immediately behind the orifice of the aqueduct of Fallopius to be distributed to the utriculus, and to the ampullæ of the superior vertical and horizontal semicircular canals. The second branch of the vestibular nerve is distributed to the sacculus; and the third to the posterior vertical semicircular canal.

"The cochlear nerve penetrates the funnel-shaped depression at the bottom of the auditory canal, and proceeds from it through the numerous foramina, by which its wall is pierced in a spiral manner, to the lamina spiralis of the cochlea.

"The mode of distribution of these nerves has been already described.

"The labyrinth receives nerves from no other source but the portio mollis, unless we suppose the portio intermedia to consist of filaments from the facial which accompany the ramifications of that nerve into that part of the ear."

APPENDIX.

Pituitary Gland.

The pituitary body, inasmuch as it presents the usual characteristics of glandular structures, would be more accurately denominated the pituitary gland, a term which conveys its real nature.

The pituitary gland, in the absence of an excretory duct — unless indeed the infundibular process attached to it is to be considered as such — would appear to be allied to the vascular glands, while in some other respects it resembles the ganglia of the sympathetic, which also are glandular organs.

It consists of two lobes, an anterior and a posterior, which differ from each other in size, colour, and consistence; the former is considerably the larger of the two, is of a yellowish grey colour, and of much firmness and density; while the latter is grey and soft, and scarcely differs in consistence from the grey matter of the cerebrum.

As the two lobes differ in colour and consistence, so are they somewhat different in structure also; the anterior or denser lobe is made up of numerous granular cells, very various in form and size, and many of which are in some cases of very considerable dimensions; these cells lie in meshes of fibrous tissue which separate and parcel them out, each of the larger cells occupying separately an entire mesh. (Plate LXIX. *fig.* 8.) The posterior lobe differs from the anterior in the smaller size of its cells, and the less amount of fibrous tissue which enters into its composition.

The pituitary gland is connected with the brain by means of the infundibulum, the small extremity of which is attached to the superior concave surface of the gland, and is united principally to the posterior lobe, which it also resembles in structure, containing very many grandular cells in its parieties.

This gland resembles a ganglion of the sympathetic in the large size of its cells, and in the arrangement of its fibrous constituent; but differs from it in the irregular form of the cells, and in the absence, so far as has been yet ascertained, of tubular nerve fibres.

Pineal Gland.

Notwithstanding the interest which exists in the minds of most persons in reference to this body, and which has arisen in consequence of the strange physiological speculations of which it has been the subject, its structure yet does not appear to have been examined with that amount of care which has now been bestowed upon most of the other organs which enter into the constitution of the human fabric; not, however, that its organization is uninteresting or difficult to be understood, for this, while it is complex and singular, yet admits of easy determination.

The chief bulk of the pineal gland is made up of innumerable minute granular cells which, when carefully examined in a perfectly fresh subject, are seen to be of the caudate form, the rays of the cells being exceedingly delicate and slender, and apt, therefore, to be entirely overlooked.

Imbedded in this cellular matrix, and, for the most part, collected in the centre of the organ, there may be noticed numerous particles of stony hardness of various sizes, and mostly of a rounded form, and the larger of which are plainly visible to the naked eye. Of these bodies, I have never encountered any satisfactory description; they are not, as generally considered, mere inorganic and earthy particles, but structures of a definite and complex organization, constituting an essential element in the composition of the pineal gland. When viewed with the half or quarter inch object-glass, the larger of these bear much resemblance to masses of fat, each being composed of numerous distinct and aggregated lesser pieces or particles which reflect light strongly, and it is in this circumstance as well as in their large size, that the resemblance borne by these bodies to masses of fat consists. (Plate LXIX. *fig.* 7.)

In the natural condition, these bodies are hard and brittle; after, however, the application of dilute nitric acid, they become soft, the earthy matter being dissolved away, and nothing remaining but their animal constituent; this, if the acid employed has not been too strong, still retains, to a great extent, the size, form, and appearance of these bodies, previous to its action, and will now readily be seen to exhibit a cellular structure, a cell corresponding to each of the bright constituent pieces above described. If, however, the acid employed be somewhat stronger, these bodies undergo a singular change in form and appearance, the cellated spaces become almost lost to view, and these compound structures assume the characters of large and spherical cells exhibiting numerous concentric lamellæ. The earthy matter, then, is contained in these cells or cellated spaces; the acid dissolves this away, and the entire body becomes so soft, as to admit readily of being torn to pieces with needles; in this state, its structure may be easily determined, and is seen to consist of membranous elastic tissue.

These bodies originate in exceedingly small and bright circular discs, which when seen with the quarter inch object glass, are less in size than the head of a pin; in these appear first, one, and, afterwards, other divisions, indicating the compound and cellular character, which they ultimately more completely exhibit.

The earthy matter entering into their composition, consists of phosphate of lime, a small portion of phosphate of magnesia, and a trace of carbonate of lime.

Minute sandy particles have been described connected with the choroid plexuses, and that portion of the velum interpositum which invests the pineal gland; whether these bodies are of the same nature as those occurring in the gland itself, I am unable to say, not having myself detected them in either of the above situations.

These bodies, which are almost peculiar to the human subject, are stated not to occur in the pineal gland, until after the age of seven years.

In addition to the above described essential elements of every fully formed human pineal gland, I encountered on one occasion two large round cells or bodies containing dark nuclei of a compound character; these appeared to be some modification of the sabulous bodies already described.

The pineal gland is copiously supplied with blood vessels, is traversed sparingly with delicate nerve tubules, and contains a small quantity of an exceedingly slender form of fibrous tissue, which possibly proceeds from the caudate cells already noticed.

The Pia Mater.

The pia mater, the vascular membrane of the brain, is composed of fibrous tissue and blood-vessels; over the surface of the brain and its convolutions, this membrane is delicate and highly vascular, while over the spinal marrow, it is thicker and less freely supplied with vessels.

In the ventricles, this membrane forms the choroid plexuses and velum interpositum; in the former, it is thrown up into numerous processes or villi, each of which is furnished with a large looped blood-vessel, and its outer surface, like the villi of the intestines, is clad with a very evident epithelium. (Plate LXIX. *fig.* 9.)

This epithelium, according to many observers, is of the ciliated kind; the cells composing it, are polygonal, somewhat flattened, and as Henle* long since noticed, furnished at their angles with spinous processes; these are only to be seen in perfectly fresh subjects, and it is probable that in some cases, they have been mistaken for cilia; not, however, since the fact has been attested by several witnesses, that I would deny the existence of ciliary processes on the cells of this epithelium.

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* Anat. Gen. t. i. p. 233.

The Pacchionian Glands.

The Pacchionian Glands are found among the vessels of the pia mater on the edges of the cerebral hemispheres, and are described as granulations composed of an albuminous material; they push before them the arachnoid membrane, project into the longitudinal sinus, and, in some cases, even occasion absorption of the parietal bones, lying imbedded in little pits or recesses. They are stated not to occur in early life, and they are frequently absent in the adult.

I have encountered on the surface of different portions of the pia mater, usually near to the sulci of the convolutions, little masses or bodies of two forms, apparently very distinct; in the first, these were opaque and whitish, and consisted of a capsule of fibrous tissue, enclosing a number of minute granular cells; in the second, the masses appeared to lie free amongst the vessels of the pia mater, and each broke up readily on being touched into several other smaller granulations of the same character: these examined with the microscope, were seen to be made up of numerous dark looking bodies very irregular in form and size, and which appeared to be of a fatty nature.

*Observations on the Development of the Fat Vesicle.**

"When the difficulty of determining the exact structure of the fat vesicle is considered, — a difficulty arising from the extreme tenuity of its cell-wall, and the opacity of its contents, — it is scarcely surprising that we should yet be without any consistent account of the modes of development and growth of the fat vesicle.

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* By the Author. "Lancet," January 20th, 1849.

"This hiatus in the structural history of that peculiar animal tissue, fat, the present brief remarks are intended in some measure to fill up.

"When the little fatty masses which are met with so abundantly in the neck, in the neighbourhood of the thyroid and thymus glands, as also in some other situations in a fœtus nearly or quite arrived at maturity, are examined, it will be observed, by the use of a lens only, that these masses are each composed of a number of distinct and opaque bodies of various sizes, presenting a smooth outline, having a more or less rounded or oval form, and held loosely together by fibro-cellular tissue, the extension of which forms the envelope which invests each of these bodies. It will also be further noticed, that each mass of fat is supplied with one or more blood-vessels, and that these break up into numerous lesser branches, one of which goes to each of the previously-described bodies, being conveyed to it by the connecting fibrous tissue; and that, having reached this body, it undergoes a further subdivision, the branches extending over its entire surface.

"In continuation of these observations, it will be remarked, that each of these peculiar bodies bears a close resemblance, in its general aspect, to a lobe of a sebaceous gland — a resemblance, which, as will be seen almost immediately, extends even to its internal structure.

"If a number of these bodies be torn into fragments with fine needles, and be examined with a half or quarter-inch object-glass, it will be observed that the cavities of some of them are filled with cells of a large size, and which again are occupied with numerous globules of various dimensions, presenting many of the characters of oil globules, but being of greater consistence. (Plate LXIX. *fig.* 10.) These cells, save by their somewhat larger size, it is impossible to distinguish from the perfect cells of sebaceous glands; so complete indeed is this resemblance, that at first sight I did not hesitate to regard them as belonging to some sebaceous gland, and which I was much astonished to encounter in such a situation. Others of these peculiar bodies, which may be termed 'fat cysts,' contain a mixture, in variable proportions, of these compound cells and of free globules, which, however, it is to be observed, are generally of larger size than those contained within the compound or parent cells. Lastly, others of these bodies enclose no compound cells, but are filled with globules of still larger size. (Plate LXIX. *fig.* 11.)

"Now the curious part of this history is, that it is these globules which go on increasing in size, and, bursting the envelopes which contain them, ultimately become what are ordinarily regarded as the true fat vesicles.

"In the article Fat, in an early number of the 'Microscopic Anatomy,' I noticed the fact, that the fat vesicles of children are not so large as those of the adult; this fact it then appeared to me had an evident relation to the growth of the fat vesicle, and it suggested the idea that the fat corpuscle was of very slow growth, not attaining its full dimensions until near the adult age; and that it was permanent in its character, enduring throughout life. This idea gathers increased weight, and, indeed its correctness is rendered almost certain, by the additional observations just cited on the development and growth of the fat vesicle.

"It would appear, therefore, taking into consideration all the foregoing particulars, that the principal development of fat vesicles takes place in the advanced fœtus, and in the early years of life (for I now remember having met with 'fat cysts' in the great omentum of children of five and six years of age, although at the time of observing them I did not know their nature and meaning), that what are usually regarded as the true fat vesicles or cells, are first contained in parent cells, and lastly, that they are slow in their growth, and persistent throughout life.

"I infer also further, from the foregoing facts, that the ordinary fat vesicles are incapable of acting as parent cells and of reproducing their like; an inference which might be fairly entertained on other grounds — viz., the difficulty, not to say impossibility, of detecting nuclei in them, and the absence of those granules amongst their contents which are so characteristic of true cells, and which there is so much reason to believe are the real germs of the future generations of cells.

"From comparative observations it would appear that the development and growth of fat proceed at different rates in different localities of the same body, it being more advanced in one situation than in another; and also in the same parts in different children of the same age; so that an exactly similar condition of things to that which I have described as existing in the masses of fat which occur in the region of the neck in the mature fœtus, must not in all cases be looked for.

"The structural resemblance which I have shown to exist between fat cells in an early condition of their development, and the cells of sebaceous glands is most interesting, the latter appearing to be, in fact, simply fat in a rudimentary and imperfect state of its development."

On the Structure and Formation of the Nails.

Since the publication of the article contained in this work on the structure of nail, some further observations by Mr. Rainey, on the same subject, have appeared; the more important of these are contained in the following extracts*: —

"The object of this paper is to show that the nails consist of at least two distinct structures: one proper to them, the horny structure, and the other the cuticular one; and also, that their matrix possesses one set of vessels expressly for the secretion of the horny part of the nail, and another set for the formation of the cuticular portion; and that besides these, there are other vessels differing in their characters and arrangement from the preceding, and probably intended to furnish a material, intermediate in some of its properties between horn and cuticle; and destined to blend these together, and thus to preserve their union during the growth and protrusion of the nails. However far this idea may be correct, the anatomical fact of there being these three different arrangements of vessels is indisputable.

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* On the Structure and Formation of the Nails of the Fingers and Toes. By G. Rainey, Esq., M.R.C.L. Transactions of the Microscopical Society, March, 1849.

Structure of the Nails.

"If a thin vertical section be made lengthways through a finger-nail from its posterior to its anterior or free margin, the external or dorsal surface of that portion of it which was lodged in the groove between the matrix and the semilunar fold of skin projecting from the dorsum of the finger, is seen covered by a thin layer of cuticle, which extends backwards as far as its posterior border, which is generally jagged and uneven, and forwards upon its dorsum. This portion of cuticle is immediately continuous with that overhanging the root of the nail, and although it is not inseparably blended with its horny substance, yet it is sufficiently adherent to be carried forward with it during its growth and to remain intimately attached to its dorsal surface until it is worn off by friction or some other mechanical cause. The palmer surface, near to its free border, is also seen covered by cuticle, which in like manner divides into two parts, the one becoming continuous with the cuticle covering the end of the finger; the other passing backwards along the palmer surface of the nail as far as the lunula, where it imperceptibly terminates. This portion of cuticle gradually diminishes in thickness as it extends backwards, and is more intimately connected with the horny part of the nail than was the cuticle on its dorsal surface. Between these layers of cuticle the proper or horny matter of the nail can be distinguished, presenting fine, nearly parallel, and generally semi-elliptical lines, with their concavity looking in different directions in different parts of the same section, and also a multitude of darkish-looking corpuscles, when viewed by transmitted light, of various forms and sizes. These compose the substance of the horn of the nail, and the lines are the cut edges of the laminæ of which it is made up. The horny part of the nail does not increase in thickness after it has extended beyond the lunula, the apparent increase of the nail anterior to this point being derived from the cuticle formed upon the anterior part of the matrix.

The Matrix of the Nail.

"A mere inspection, even in the living subject, of the parts situated beneath the nail, is, in consequence of its transparency, sufficient to give a general idea of the relative vascularity of the various parts of its matrix. The upper part of the matrix is seen to present a pale, semilunar space, called the lunula. The greater part of the lunula is concealed by the semilunar fold of integument which projects over it; but extending a little below this fold the lower portion of the lunula is visible, presenting a curved border, with its convexity looking downwards. Immediately below the lunula, and circumscribing its inferior limit, the matrix has a reddish colour, which gradually becomes fainter towards the free margin of the nail, but which deepens considerably where the nail becomes detached from the integument.

"When the matrix is fully injected and the nail removed, the part corresponding to the lunula presents several rows of convoluted capillaries: the individual convolutions have different degrees of complexity, from a simple loop a little twisted round itself, to a complex tuft of vessels. These rows have their direction from above to below, they are all slightly curved, being concave towards the median line of each nail, and the most external ones are nearly parallel with its lateral margins. These, being the vessels which secrete the horny part of the nail, may be called the horn-vessels. Superiorly these vessels are separated from the rich plexus on the fold of integument which overhangs the nail, by a fibrous and almost non-vascular groove, in which the free border of the nail was lodged, and where the cuticle covering its root terminates. A few vessels, however, pass across this groove from the horn-vessels to the plexus just mentioned. Inferiorly the horn-vessels communicate with quite a different arrangement of capillaries, which run in a more straight course, and are much more crowded together than the horn-vessels. These vessels run nearly parallel with one another, in a direction from behind forwards, and being very near together, render this the most vascular part of the matrix; and produce that redness immediately below the lunula upon which the form and degree of distinctness of its lower border is dependent. Just below these vessels the surface of the matrix begins to be raised into numerous plications or folds, passing directly forwards, and increasing in depth as they approach the free extremity of the nail, where they become continuous with the raised lines observable on the ends of the fingers. These plicæ consist each of a fold of basement membrane, enclosing a series of loops of vessels. At first these loops are small and simple, but they become larger and more complex, as they advance towards the end of the finger, where they are continued from the ridges of the matrix of the nail into those of the skin of the finger, in which they are generally very complex. When the nails are *in situ*, these ridges are received into corresponding grooves in their inferior surface. Near the part of the matrix where the plicæ commence, several distinct circular or oval openings are sometimes seen passing for some depth beyond the surface, and appearing like follicles or lacunæ. These are frequently closed by the opposition of the adjacent plicæ, and thus their presence is rendered doubtful, but they can be seen very distinctly either when some of the material which they contain has been recently removed, or still remains within them in the form of whitish, globular masses. The situation of these lacunæ, where the openings themselves are not apparent, can be distinguished by the plexus of capillaries in their vicinity, in the areolæ of which their openings are situated."

On the Ganglionic Character of the Arachnoid Membrane.

The following extracts contain the more important portions of Mr. Rainey's observations "On the Ganglionic Character of the Arachnoid Membrane of the Brain and Spinal Marrow"*: —

"The first idea which suggested to me the resemblance of the arachnoid to the sympathetic, was from the examination of a piece of the former taken from the inferior and lateral part of the medulla oblongata, when I observed, at the meeting of two of the chords situated between the arachnoid and pia mater (called by Mengendie "Tussu Cellulo-vasculaire sub-Arachnoide"), a triangular body of the form and general appearance of a ganglion, very similar to such as I had seen in small animals.

"This resemblance appeared more striking on observing a branch going from the chord connected with this body, to the arachnoid membrane, along which it ran for a considerable distance, dividing and sub-dividing in its course, in the manner of a nerve; the successive sub-divisions becoming more and more minute, and at the same time interlacing and enclosing small areolæ filled with corpuscular matter. These corpuscles were so blended with the ultimate filaments of this chord as to render indistinct their exact mode of termination.

"Such was the connexion of one extremity of one of these chords. The next point to be determined was the structure to which the other extremity of the same chord had been attached. As, in this case, it had been separated from its connexion, this could only be ascertained by examining similar chords in other portions of membrane. This examination being made, I found that the end in question terminated either on an artery or on a cerebro-spinal nerve. In the former case a chord, as soon as it comes in contact with an artery, divides into branches which ramify upon it, and run along its external coat, just as, to all appearance, the branches of the solar plexus do on the small arteries supplying the viscera in the abdomen. If the cerebral artery be rather large, and situated between the arachnoid and pia mater, some of the branches going from a chord form upon it a plexus, and others proceed onwards to the vessels of the pia mater.

"In some instances a chord passes from an artery to the arachnoid without dividing in its course, as just described; but more frequently on approaching the latter it sends off three or four large branches, which pass to different parts of the membrane, and ramify in it, as before explained; however, sometimes one of these branches either itself expands into a large dense plexus, or joins other branches to form one, from which plexus two, three, or more chords pass into the substance of the arachnoid. The shape of these plexuses is either square or triangular, according to the number of branches which join them, and the number they give off. Besides consisting of interlacing fibres, they also contain corpuscular matter.

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* Medico-Chirurgical Transactions, 1846.

" The arachnoidal extremity of some of the chords connecting the vessels with the arachnoid of the cauda equina expands, close to the membrane, into a large oblong and rather oval bulb, the axis of which is occupied by a continuation of the chord, extremely convoluted and bent upon itself; whilst, inferiorly, its fibres are blended with those of the membrane.

" The chords which pass from the vessels of the pia mater, at the upper portion of the brain, to the arachnoid, terminate in the latter by fibres having a stellate arrangement. There are also some large triangular plexuses like those at the base of the brain, from which branches descend between the convolutions to the vessels within the sulci.

" In the lower animals, as in the sheep, in which the cerebral convolutions are small, the stellate fibres are the best seen. They can even be distinguished by the naked eye, appearing like minute opaque points. At their centre, the fibres of which they are composed, seem to be blended into an irregular confused mass, from which other fibres radiate, and lose themselves in the cerebral surface of the arachnoid. Some fibres go from one stellate body to another, and others can be traced into the coats of the vessels : these latter are by no means numerous. Branches also descend (still having somewhat the stellate disposition) between the convolutions to the deep-seated vessels; these filaments are much more numerous upon some vessels than upon others, and they do not appear to extend so far as the capillaries, no fibres of any kind being visible upon this system of vessels.

" It appears, from what has been stated, that the disposition of the ramifying filaments of the arachnoidal chords, and the form and size of the gangliform plexuses connected with them, bear some proportion to the number and size of the vessels in their vicinity. Hence, about the base of the brain, where the branches of the arteries are large, the plexuses are also large, and of an irregular shape, whilst on its upper surface, where the vessels are comparatively small, and more equal in size, and have a more uniform distribution, the plexuses also are smaller, more numerous, and more regular in their shape and volume.

" Besides the plexuses situated in the course of the chords of the arachnoid, there are others which are more intimately connected with its cerebral surface, and which, in some situations, appear to compose the entire thickness of the membrane.

" In these plexuses, the filaments interlace very much in the same manner as the nerves do in the plexuses of the cerebro-spinal and sympathetic systems. A chord, for instance, when traced into one of them, will be observed to break up into its component filaments, the adjoining bundles of which interlace, yielding to one another one or more bundles, and the chords which emerge from the plexuses deriving their component filaments from different bundles: these bundles, and their component threads, during their interlacing, will be seen to preserve their individuality.

"When a chord going from the arachnoid, terminates on a cerebral nerve, it divides in the same manner as an artery, some filaments ascending and others descending, along with the nerve tubules. In some instances this extremity terminates in a sort of membranous expansion, which encloses several nerve tubules."

Mr. Rainey, in the next place, enters upon the consideration of the nature of the above-described apparatus of ramifying chords and plexuses, and arrives at the conclusion, derived from their relations and intimate structure, that they are composed essentially of gelatinous or sympathetic nerve filaments.

"In the chords of the arachnoid (he writes) I could distinguish three different kinds of filaments, all which exist in the branches of the sympathetic.

"One species, generally considered the most characteristic, is the nuclear fibre described by Henle; it is a flat, clear fibre, with oval, nearly equidistant nuclei, and each having its long axis corresponding to that of the fibre. I have found these fibres in the arachnoid, but they are very rare. I have seen such going from the arachnoid to the coat of the internal carotid, the trunks being blended with the membrane, and the branches connected with the artery. I also found, that as the fibres branch off from these trunks, and intermix with others, they lost their nuclei, became more pale and clear, and differed in no respect whatever from the other fibres of the membrane. Besides, I have seen these fibres in other parts of the membrane, and they exist chiefly on the exterior of the larger chords. This species of fibre I have also found to be very uncommon in the smaller branches of the nerves confessedly sympathetic, especially in those most remote from the ganglia and larger trunks. The next kind of fibre is one consisting of bundles, for the most part rather smaller than nerve tubules, of very minute wavy filaments, intermixed with small particles of granular matter, having no definite form, size, or position in respect to the filaments. Some of the chords of the arachnoid are made up entirely of fibres of this description; in others they exist chiefly on their surface, being most abundant near their attachment to the arachnoid, upon which they are continued. This kind of fibre exists abundantly in all the branches of the nerves undoubtedly sympathetic; and also, more or less, in those connected with the ganglia. The third kind of fibre occurs in the form of roundish, though sometimes flat chords, composed of extremely minute wavy filaments, either collected or not into bundles, but apparently interwoven somewhat together, so that, generally, a filament of only an inconsiderable length will admit of being detached mechanically from the rest, and, when thus separated, its breadth is very unequal, and its contour ill-defined. These filaments are often totally destitute of granular matter.

" This last species of fibre is very common among the chords composing the plexuses of the arachnoid; it is also sometimes situated in the centre of the larger ones, surrounded by the second species of fibre; this can be detached mechanically, and exhibited separately under the microscope.

" In the nerves obviously sympathetic, this kind of fibre exists in considerable abundance in those branches of the solar and other plexuses which are most remote from the ganglia.

" Thus far my observations have been confined to the structure of the fibres of the arachnoid, and their supposed use. I will now consider the corpuscular or ganglionic part of this membrane. Some of the plexuses on its cerebral surface have the interstices formed by their interlacing fibres, completely filled up with small roundish corpuscles, about the size of blood-discs; whilst, in others, these fibres are covered with irregularly-oval masses of them. On this surface also, in various situations, there are well defined round or oval bodies, having in their centre a granular nucleus surrounded by fibrous tissue, intermixed with more or less corpuscular matter. Some of these bodies are connected to the fibres of the arachnoid by a very fine thread, others are situated at the conflux of two or more fibrous chords, and their diameter varies from that of two to seven blood-corpuscles. They are generally solitary and not numerous; but as they have been present in the arachnoid of every human subject which I have examined (a number exceeding twenty), they cannot be regarded as accidental or adventitious. At present I cannot decide as to their nature or office, not having seen anything which they exactly resemble in other parts of the body; at any rate, they look more like small ganglia than anything else I have seen.

" Besides these corpuscles, which, as before stated, exist on the cerebral surface of the arachnoid, I have met with some of a very different character, situated in its substance, though nearer to the cranial than to the cerebral surface. The most ordinary appearance which these present, when seen by transmitted light, is that of a section of an urinary calculus made through its centre, appearing, like it, to be made up of concentric layers. When viewed by reflected light, these bodies seem to be vesicular, and filled with fluid, the quantity of which appears to diminish as the number of layers increases, so that those in which the laminæ have extended as far as the centre, are almost flat. Although the most frequent form of these bodies is circular, yet some are oval; occasionally they are connected with a fibre of the arachnoid, in such a manner as to resemble small Pascinian corpuscles. One remarkable fact connected with these bodies is that they occur in the arachnoid of almost every subject which I have had an opportunity of examining, and that no part of the membrane is exempt from them; generally they are solitary, and very sparingly distributed; but sometimes they are in clusters. I have found them in the internal Pacchionian glands mixed with granular matter, and the same kind of fibre as exists in most parts of the arachnoid membrane. Their diameter varies from 75,000 to 39,800 of an inch. I have observed on some parts of the arachnoid, in the vicinity of a cluster of these bodies, cavities of a similar shape and size, from which the corpuscles themselves appear to have been dislodged. From this circumstance, as well as from the general aspect of these bodies, they seem to me either to be structures altogether adventitious, or the result of an abnormal deposition in diseased corpuscles. The tendency which they may be observed to have to coalesce when several smaller ones occur together, evident by the obliteration of those portions which seem pressed against one another, and the union of the remote segments to form a single outline enclosing an area whose figure clearly indicates the number of corpuscles which have united to form it, proves them to be something more than mere earthy deposits, such as are sometimes found in the choroid plexuses, or even than mere scrofulous tubercles. Vogel has found bodies similar to these in the choroid plexuses; in these, and in the pia mater, Dr. E. Harless has also seen them, and given a very minute account of their structure in a number of Müller's Archives, 1845. This author seems to think that their seat is in the arteries, and that they are somewhat allied to ossification of these structures; but their occurrence in all parts of the arachnoid, in some of which there are probably no vessels, is opposed to this view."

Mr. Rainey regards the corpuscles constituting the epithelium of the choroid plexuses as ganglionary, and details his reasons for this opinion; hese, however, cannot be admitted to be decisive on this point.

"As respects the supply of vessels and cerebro-spinal nerves to the arachnoid, I may observe, that the arteries are few, but rather large, almost sufficiently so to receive a small injection tube; (I have preparations of these;) and that cerebro-spinal nerves may be traced into its visceral portion, and, with the microscope, their tubules can be seen running along with the arachnoid fibres, into which they appear, from the gradual loss of their tubular contents, to degenerate."

Structure of the Striped Muscular Fibrilla.

At page 341., doubts were expressed as to the correctness of the view entertained by Drs. Carpenter and Sharpey, in reference to the structure of the striped muscular fibrilla. At that period, the author had not seen any of Mr. Lealand's preparations, on the examination of which the above-named gentlemen founded their opinion; he has since, however, been favoured by Dr. Carpenter with the examination of his own specimen, and this would certainly appear to bear out fully their opinion of its cellular constitution.

Structure of the Bulb of the Hair.

Further opportunities of examination have satisfied the author that the vesicle which he has described as forming a portion of the bulb of the hair has no existence, and that this rests immediately upon a compound vascular and nervous papilla.

The Synovial Fringes.

The synovial fringes consist of branched and elongated threads or filaments, which taper to a point, and each of which is supplied with one or more, according to its size, contorted and looped blood-vessels; these, however, do not reach the whole length of each thread, but terminate at one third or one half its length. It is in the terminations of these filaments, according to the observations of Mr. Rainey, that those cartilage-like bodies sometimes found loose in the joints, especially the knee joint, are first formed. The threads or filaments of which the synovial fringes are constituted are of such length and so much branched, that they might, at first sight, be mistaken for those of some conferva of the genus *Cladophora.*

On the Anatomy of the Sudoriparous Organs.

Mr. Rainey * describes the duct of the sudoriparous glands as consisting of two distinct portions, an epidermic and dermic.

The *epidermic* portion is of a conical form, the base being directed towards the surface, and the apex situated in the midst of the cells which form the deep layer of the epidermis; it is constituted of cells which are flattened and elongated, and the long axes of which are disposed in the direction of the length of this portion of the duct: below, near its termination, the cells are thicker and less flattened.

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* On the Minute Anatomy of the Sudoriparous Organs. By G. Rainey. Royal Med. and Chirur. Society. See "Lancet," 1849.

The *dermic* portion of the duct is also of a somewhat conical shape, its base being in like manner directed upwards, and its parieties being continuous with the basement membrane of the dermis; this portion, therefore, is of a totally different structure from the former; it is described by Mr. Rainey as being lined by a layer of epidermic scales, which get gradually indistinct towards the gland, and its upper or expanded part as receiving the termination of the epidermic division of the duct.

This description of the duct of the sudoriparous gland, so far as I have been able to follow it, would appear to be in its main particular correct, it consisting, as stated, of two portions, an epidermic and a dermic; the former is scarcely to be regarded, however, as anything more than an appendage to the dermic part, which is the true duct, it being little more than a definite channel through the epidermis.

It seems to me, however, to be incorrect to describe the epidermic portion of the duct as commencing in the deep layer of the epidermis; it extends beyond and far deeper than this, for it lines the whole length of the true duct, and this not merely with loosely aggregated cells, but these are so united together as to form a distinct tubular membrane, which by maceration may be exhibited as such (see Plate XXIII. *fig.* 2.); the epidermic cells become, in fact, continuous with those of the sudoriparous gland itself.

Mr. Rainey has noticed the fact that the secretion of the sudoriparous glands in the palms of the hands and soles of the feet, where the sebaceous glands are entirely wanting, is of a greasy character; from this circumstance he draws the conclusion that these glands secrete both sweat and sebaceous matter, the former in their more active state, the latter in their less active condition.

It is only in the hands and feet, where the epidermis is thick, that the epidermic portion of the sudoriparous duct assumes importance.

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